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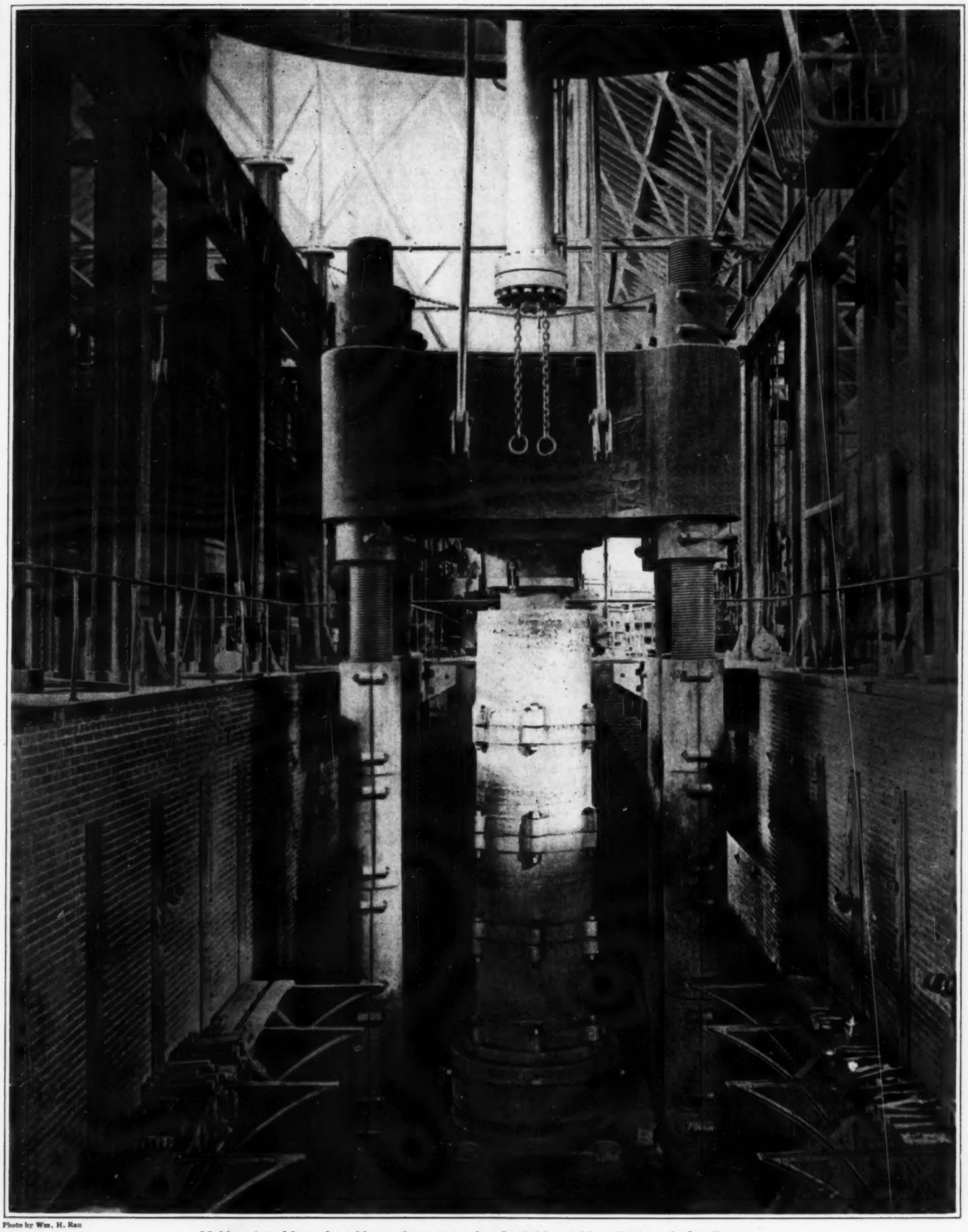

Photo by Wm. H. Rau

Making a steel ingot for a big gun by compressing the fluid metal in a 7000-ton hydraulic press

BIG THINGS IN STEEL [See page 56]

The Heavy Oil Engine—I*

A Review of the Present Construction and Future Development

By Charles E. Lucke, Professor Mechanical Engineering, Columbia University, New York City

THE heavy oil engine is of particular interest at this time because those who are familiar with the problem believe a change is coming in the situation. It is my intention to present, in a more or less informal way, some of the ideas involved in the development up to the present time and also those which lead us to believe that a change is about to take place, and in about what direction. What I say is somewhat in the nature of a prediction, although he is a bold man who undertakes to make a prediction on these matters. Nevertheless, I am inclined to have a little more confidence than usual because about a year ago I talked to you here about aeronautical engines, and showed those who were not already familiar with that fact from what a chaotic state the art of aeronautical engine construction was emerging, and ventured to lay down some general lines of practice that seemed to be proper and a good basis for future work to follow.

Since that time this country has been drawn into the great war, and likewise since then the Liberty motor has been designed and put on a manufacturing basis. A good many ideas that were presented a year ago before the inception of that motor, and before there were standards of any kind, have been incorporated in it. A number of the things which were then not standard and which were recommended as standard have since become standard.

I feel, therefore, somewhat more confident in the sort of prediction to be made tonight on the heavy oil engine.

It may be of interest for me also to say here that as a result of the war my entire time, to the exclusion of all other things, has been devoted to the subject of internal combustion engines for the navy service. The Navy Department has established at Columbia—about the Mechanical Engineering Department, as a nucleus—the official United States Navy Gas Engine School, and over nine hundred men have been given, all without any internal-combustion experience before they came, a four weeks' finishing course of training and have been turned out into the service. Of those men, the leading engineers of over two hundred of the submarine chasers form a part. That work is now going on and will continue until all these boats have been manned with trained men.

It is interesting to note, also, that these boats were non-existent a year ago; they did not even exist completely on paper, and before a year will have passed from the time when they were paper things there will have been completed, and in the water and completely manned and officered by trained men, over three hundred of them. Even though that is a small matter in the naval program, it is nevertheless an accomplishment that all ought to feel proud of.

The gas engine school at Columbia University is also now undertaking to train the engineers and leading mechanics to take charge of the motors for the navy foreign flying base station service. I mention that because I want something from you in that connection; to help secure fine, competent internal-combustion engine men who are also machinists, and therefore the kind of men that can safely be trusted with the enormous responsibility of proper maintenance of an aeronautical motor, the failure of which may cause the sacrifice of life. We will not undertake to train any man who is not at the start a pretty good man—at least from the experience standpoint. We are not finding these men at the present time as fast as we need them, so I am mentioning this fact with the idea that those of you who are here and who know such men will let me have their names, or at least tell them to apply for that class of service, if they like it, and I will see what can be done to bring them in. The leading men will receive the rank of Ensign in Class 5, the Naval Reserve Flying Corps, and will have the job of Engineer Officer.

To return to the subject, the heavy oil engine. The heavy oil engine in this country has never amounted to very much. That fact itself should prompt some inquiry, because this country is the home of petroleum.

The heavy oil engine as an internal-combustion engine has so far proved itself to be capable of the highest known thermal efficiency in transforming the heat of combustion into work. Efficiencies approaching 40 per cent are normal, and in some rare cases this is exceeded. This is not equaled by any other system that has ever been produced.

Putting those two facts side by side, you will see a cause for wonder at once. Here is America producing more petroleum than any other country in the world, and doing it for a long time back—something like fifty years—and yet the motor that operates with this oil—the most efficient known—the heavy oil engine in this land of petroleum is, compared with other classes of machinery, practically a failure. It is a failure in the sense that the business of producing it has not expanded materially, and it has been in general an unprofitable business. No one in this country has made much, if any, money in building oil engines, and a great many who have thought of going into the business with excellent prospects, good plans, and plenty of capital behind them finally decided not to do so on the record of failure to produce dividends on the part of those who are already in.

There has been from the beginning great interest in the oil engine. It is a thing attractive to the mind. Everybody thinks about it. And yet, on the commercial side, there has been very little demand—not sufficient demand anywhere to warrant any really large establishment confining itself to the production of oil engines with a competent engineering staff and research department such as would be necessary to do the thing right. This lack of demand is rather difficult to explain, but it is nevertheless real. Assume it to be a fact, without investigation, and put it down as the first of the various causes for lack of development. The next cause is the fact that this is the land of petroleum, and therefore the land where petroleum and its products are held in least value. In other words, we are prodigal of petroleum and have not the inducement, by reason of our multiple supply, to economize it. In the place where oil is so plentiful naturally it is not regarded as a valuable product—not nearly so much as in a distant country, where its cost is high. That fact makes the high efficiency mentioned before lose its attractions, and when it is remembered that the machine to produce this high efficiency is a costly machine, therein lies the elements of financial balance that turn the wrong way.

The cost of power, when it is the controlling factor—and that is usually the case in stationary installations—is made up of two charges: fixed and operating. The fixed charges are based primarily on the first cost of the engine, and the heavy oil engine has always been an expensive engine—never less than $60 per horse-power and often as much as $80 per horse-power. On the other side is the operating expense, the principal item of which usually is the cost of fuel. The more highly efficient is the engine, in fuel consumption, the less will be the fuel cost per horse-power-hour, and therefore the more prominently this heavy fixed charge will stand out.

In all cases where the cost of power is the controlling factor these financial facts are to be laid beside the fact of the lack of demand for these oil engines. Nevertheless, as time goes on, inventors, designers, and research men are not deterred from trying out schemes, so that, in spite of this lack of financial and business encouragement, there is a very considerable degree of progress—much slower than it ought to be, but nevertheless real. Unfortunately, in this case the public in general is not informed about this progress, and therefore when, due to a change in economic conditions, the time comes to make use of all the available information on the subject, we suddenly wake up to the fact that it is in the hands of a few people and the rest of the public knows nothing about it.

The present is a time of change, and there are two reasons for that. In the first place, the war has brought about a shipping situation which is unprecedented in the history of the world. There is a demand for ships today such as never existed before, but there is at the same time just as real and as strong a demand for the men to run those ships. The heavy oil engine is one of the various possible ways of driving a ship, providing the ship be not too large. Its fuel economy is a direct value in ship operation, since it gives a larger cruising radius or the maximum possible cargo capacity. It, furthermore, is peculiarly adapted to a ship, in view of the fact that we are facing a labor shortage in ship operation, and the heavy oil engine ship can be operated with less men below the deck than any other type of vessel ever produced—except, of course, the small gasoline boat. The war, then, has brought to our attention this heavy oil engine as a possible motive power for the smaller of these new merchant vessels as well as naval vessels, though more merchant than naval. And it is a fact that shipping people are considering this question today all over the country, but most of them are afraid to act. They would all like to, as near as I can find out by talking to them, but they are afraid to act. To my mind the time is not far distant when they will have to act, or lose something by not acting.

Aside from the shipping situation, there is another reason, and that is the economic reason of an appreciation of the value of this wonderful fuel that Nature has placed beneath our country's land surface. This fuel is peculiarly adapted to this sort of use: the generation of power in internal-combustion engines directly, with the highest possible efficiency and the least possible man attendance. Fuel has been wasted in this country, especially in that region near the oil fields, just because it was plentiful. Nevertheless, we are coming to the point when the people—if not the people, certainly the government—will be compelled to force the abandonment of the use of this fuel for all purposes where other kinds of fuel that can be had in more plentiful supplies would do as well. When you consider that oil or petroleum is the only kind of fuel that can be used in the high efficiency engine, then it becomes clear that to burn it to warm a living-room where charcoal or wood or coal of any grade would do quite as well as to commit a sort of economic crime. That feeling and the financial consequences of not acting upon the realization of that situation will come to a climax before very long, and result in a plan for conservation of our liquid fuel or petroleum supply, so that it shall be used for only those purposes for which it is peculiarly adapted and be barred from all other uses where other things will suffice. In the natural course of events people wait for prices to bring such a situation about, but this is not a time that properly is classifiable as belonging in the natural course of events. This is a time which is distinctly abnormal and unnatural. We hear every day plans proposed and turned down because there is no precedent, with always the rejoinder that here we are in a great war for which there is no precedent, so why follow precedents in other things? We have been forced to change in a thousand-and-one things, so let us change in a thousand-and-two things, and do it quickly.

I could expand to considerable length along the lines of the economic situation with regard to the use of oil and the peculiar adaptability of oil in the internal-combustion engine, and the particular adaptability of that class of engine to the ship service, but I want you to realize that there is another field also where there is a demand slowly but surely growing up, and that all these separate demands, coupled with the growing change in the economic situation, must certainly, one piling on top of the other, produce a new condition which I foresee.

We have a real gasoline automobile industry, and it is becoming a great manufacturing industry, but it is today tied up to and inherently dependent upon the lighter petroleum distillates. There is no highly economical gasoline or kerosene engine, and every reason leads us to believe fundamentally that none can be produced on the present system. To make our automobiles and motor trucks and tractors run, and to make our available sources of fuel supply last, there seems to be only one solution, and the leading engineers and mechanics in the automobile industry are beginning to talk about that solution: the adaptation of the heavy oil type of engine to the high-speed class of service which such as the automobile and the tractor require. It is coming; there can be no question about it. If anybody is able today to produce the high-speed type of engine necessary, even though it costs more money to build, rest assured it will be adopted very quickly.

There is a third field, and that is the field of direct-connected electric generating sets. For a long time in the gas-engine business we built engines to drive generators in a kind of haphazard fashion. As time went on a particular type of outfit began to appear—a direct-connected, high-speed generating set, with engine and generator on one base, self-contained, the best example of which, on a small scale, is the Delco lighting outfit, which is being sold at the rate of over 50,000 sets a year now, all over the country districts. There are corresponding units of other designs in larger sizes. The fact that these sets are generally confined to gasoline limits their use, because in many places gasoline is unsafe to use; in other places it is not obtainable; in still others the cost of it is prohibitive. It is apparent that if we had the heavy oil engine adapated to that class of high-speed, multicylinder service, and with the necessary degree of regulation, it would open up still another field.

So in the field of application of the heavy oil engine I see just ready to be invaded these three things: First, a widened use for ships; second, a new use in the automobile type of motor; third, a corresponding new use for direct-connected, high-speed electric generating sets. Whether they be used on land or aboard ship, it does not

*Presented before the Engineers Club of Philadelphia, and republished from the *Journal* of the Club.

matter. If they are designed right they are serviceable in either place.

It is of interest, and particularly pertinent here, to review some of the ideas that have been developed to date, and some of the suggestions available as lines of possible development in the direction of real progress. And this review I divide, for the purpose of clarification, into two topics—functional and structural.

Under the functional come all those questions connected with the supply of air, the supply of oil, the establishment of the proper relations between the oil and air to give the desired control of combustion after the necessary compression—in fact, all those physical processes involved directly in the development of the power within the cylinder.

Under the head of structural would come all those principles of type arrangements or typical part forms, and proper proportions of the metal structure that houses these physical processes and thereby produces a machine.

The first item under the functional discussion is that of charging the cylinder with air, and this is carried out by either the so-called and well-understood 4-cycle system of two valves per cylinder, or by any one of several 2-cycle schemes. Of the 2-cycle schemes there are a number. First we have the ordinary crank-case pre-compression chamber, which is barred from any engine of more than diminutive size, because the closing of the crank case prevents access to the working parts, in addition to imposing other bad conditions. The first step in avoiding the difficulties of the closed crank case which are prohibitive in any real engine comes when the connecting rod and crank shaft are left open and the front end of the cylinder closed, the front end acting as a pre-compression or air-charging chamber in conjunction with an air reservoir, which is necessary, so that the pressure in the front end of the cylinder cannot rise too high.

This front-end compression arrangement has certain faults that have led to the design and more wide use of others. For example, it is not possible in the oil engine of the 2-cycle sort, with the front-end pre-compression chamber, to put into the motor end a volume of air equal to the piston displacement: the volume must necessarily be less than the piston displacement measured at atmospheric pressure. That being the case, some of the burned gases or products of combustion cannot be expelled, and, at the same time, the residue is hotter than it otherwise would be. To correct that, the alternative scheme of a step piston or a separate scavenging pump have been developed, more particularly the latter. The step piston is the first of the scavenging schemes, and is a scavenging scheme because the volume swept through by the step of the piston may be made larger than the volume swept through by the motor piston proper, and the excess of this displacement is the scavenging displacement. By means of it more air can be put into the motor cylinder per charge than can possibly stay there at atmospheric pressure. This being the case, the burned gases may be more completely expelled, and, what is much more important, the residue of the gases left there would be much cooler before the next compression starts.

This step piston has certain faults of a structural nature which need not be detailed, but which are responsible for the wide use of the alternative scavenging scheme of a separate low-pressure compressor, built somewhat along the lines of the old-fashioned blowing engine. This arrangement is usually double-acting, so that one such scavenging pump will serve two single-acting 2-cycle motor cylinders. With it the 2-cycle engine can then be made to perform all the things that the 4-cycle engine can do, except as to the negative work involved in the pre-compression of that surplus air; so that, while the two engines may perform somewhat the same, the 2-cycle form will be necessarily less efficient by the lost or negative work, and, at the same time, some of the so-called simplicity of the 2-cycle engine has disappeared. So completely has it disappeared that it will be found that the weight per horse-power has grown in the 2-cycle to be substantially the same as the weight per horse-power in the 4-cycle. That is to say, when you start with the simple 2-cycle idea with the hope of getting half the weight per horse-power, because of twice the number of impulses from the same amount of metal, then you have to add this and that and the other thing, and by the time you have got through adding enough to make it a real working engine the weights of both types are just about the same. Therefore the 2-cycle as compared with the 4-cycle, as to weight, might be called substantially equal. But there is an inequality in another direction. The 2-cycle, acting with more impulses per minute in the same volume, will run hotter and load the same sized bearings to a higher average bearing pressure, and, as a consequence, size for size, the 2-cycle will give more trouble with burnt pistons and overheated bearings than the corresponding 4-cycle. These are just a few of the reasons why this much-mooted question of 2-cycle *versus* 4-cycle as a means of air-charging remains a controversial matter rather than one of settled engineering practice. My own personal opinion about the matter is this: That in the smaller size, let us say up to 100 horse-power, or 200 horse-power maximum, the simpler form of 2-cycle, not with the scavenging pump, is a rather good thing and practical. In the next range of sizes, to, let us say, 500 horse-power, the 4-cycle works out best in the long run, and from that point up the pendulum swings the other way toward 2-cycle with scavenging pumps as matters stand today. But in the larger sizes the art is most undeveloped, and most of the uncertainty as to what is the proper engineering practice concentrates right there.

The next item under the functional discussion is the introduction of the oil, to form either an explosive mixture for explosive combustion or to prevent the forming of an explosive mixture so that the oil may burn non-explosively. Before examining the means of introducing and controlling combustion of the oil, I want to point out the fundamental and controlling value of a compression before injection on the one hand, and of the rate of oil burning following the right amount of compression, on the other. Consider the former point first. It can be demonstrated, and it is pretty generally understood now without demonstration, that, other things being equal, the more the air charge is compressed before the introduction of the oil the higher the mean effective pressure will be; and that, of course, is a prime factor in power and, at the same time, the higher the efficiency, the smaller the fuel consumption. It may therefore be said with practically no reservation that in an oil engine as much compression should be carried as is possible. But that is not all. After the compression has been completed, the oil must be introduced either at that time or just previously, so as to produce a suitable and proper combustion line of one of the two characteristic types or mixed.

The two characteristic types of combustion line are, first, the vertical combustion line produced by an explosive mixture, and, second, the horizontal combustion line produced by a gradual introduction of the oil, the oil burning as it comes in, and which latter system has been called the Diesel system. It is clear, of course, that we might burn part of the oil explosively, raising the pressure a fraction of the maximum, and burn the rest non-explosively, without further change of pressure. Or we might have such a slow introduction of oil as to cause the combustion line to drop as the piston moves out on the working stroke. The two types of combustion line are (*a*) the vertical explosive, and (*b*) the horizontal non-explosive, or Diesel, forms. Now, of these two methods of oil combustion as to rate, which should one choose? That question should be settled before considering the means of introducing the oil, because one is not warranted in spending time in determining how to introduce the oil until there is first a decision as to what end is to be accomplished by it. In other words, we must establish the specifications before undertaking construction.

It will be found, by comparing the full diagrams for those two combustion lines, with the same amount of oil and expansion, of course, following both, that about the same mean effective pressure is possible with both or with either. That is to say, so far as power is concerned, there is no choice. But, on the other hand, when you compare efficiency or fuel consumption, then this startling fact comes out: That the constant-pressure or Diesel kind of non-explosive combustion is capable of only half the efficiency of the other kind of combustion, the explosive sort. To put it a little differently and more precisely: If the fuel be burned explosively after compression, then an efficiency can be produced with a corresponding fuel consumption equal to that obtainable with the non-explosive Diesel combustion when the latter has twice the compression of the former. Again, to put it in still another form: A Diesel diagram with nearly 500 pounds compression produces no better efficiency or fuel consumption than an Otto cycle diagram with 250 pounds compression. There is therefore absolutely no doubt on fundamental ground as to which of these two possible modes of burning offers the best promise of results. They are equal in power possibilities and nearly two to one in efficiency with reference to compression. When I say the latter, do not misunderstand. Do not think I mean to assert that the Otto can give and always will give twice the efficiency of the Diesel—not at all. They can be made exactly equal in efficiencies and fuel consumptions with selective compressions, but when the compression is thus selected to do that thing it will require twice the compression with the Diesel as will be required with the Otto arrangement.

This is particularly interesting when you consider that fully 90 per cent of all the development work that has been done with this heavy oil engine has been done with the less promising Diesel cycle, and the very promising Otto cycle has been almost entirely neglected. I say it has been neglected, and yet I do not mean that. It has not been neglected by those people who understood the possibilities—the students of this subject. It has not attained the popularity or the standing in a commercial way of the Diesel.

In this functional study the next important consideration is the compression itself, and the relation between the degree of compression and the mode of combustion, or control of combustion. The oil has to be ignited, and there are various ways of igniting it. It must not, however, be ignited until the right time comes; that is, not until a sufficient degree of compression has been executed—whatever is desired. Therefore there must be an igniter, and the ignition, as a process, must be under control. Now, the ignition will always take place whenever any fuel in contact with air reaches the ignition temperature. The air under compression is rising in temperature and is approaching or passing the ignition temperature in that process of compression. Somewhere or another in the process of compression, if it be carried far enough, ignition temperature will be established, and ignition will inevitably occur, if there is any oil in contact with the air.

It is therefore essential, in considering the limit of compression in its relation to the introduction of oil, to have some kind of mental picture, and preferably exact figures, as to the way in which the temperature rises in compression, especially with reference to the ignition temperature as a basis of reference.

The ignition temperature of these heavy oils is a somewhat uncertain physical constant, but from my experience I am inclined to think this is very close to 950° F., or near enough to that for practical purposes.

To bring this matter before you I have prepared a little table here (see accompanying table). This table shows at the left, first column, initial air temperatures of from 200° F. to 600° F. before compression. Starting with these temperatures, then, to reach ignition temperature it would be necessary to have the compressions, indicated in columns 2 and 3. To reach temperature of 200° less than ignition temperature the compression would be as shown in columns 3 and 4. To reach a temperature of 200° F. over ignition temperature the compressions required are shown in columns 5 and 6. Or, for 400° F. over ignition temperature, the compressions of columns 7 and 8.

To explain further, starting with atmospheric air at a temperature of, say, 70° F. in an engine-room, it is drawn into a cylinder, and is bound to become somewhat heated

Compression vs. Initial Temperature vs. Ignition Temperature (*)

Initial temperature	Compression Lbs., Sq. In. above atm. (14.7) with 0.1 pound valve drop							
	Ignition temperature of 950° F.		200° F. below ignition		200° F. above ignition		400° F. above ignition	
	Min.	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*
200	190	293	104	152	305	511	467	800
300	110	155	58	79	181	279	282	460
400	67	92	34	42	114	165	175	275
500	41	52	18	22	75	101	118	174
600	23	31	8	10	47	63	79	107

Based on $S = \begin{Bmatrix} 1.33 \\ 1.40 \end{Bmatrix}$ in. $\qquad P = 14.6 \left[\left(\frac{T \text{ final}}{T \text{ initial}} \right)^{\frac{S}{S-1}} - 1 \right]$

on its way. It will become heated by contact with the hot intake ports, sweeping over the intake valves, sweeping against the interior cylinder walls, which are very hot, especially in large engines with thick metal, and finally it mixes inside with the hot products of combustion from the previous shot. So, to say that this 70° F. air will rise 130° F. and have a temperature, therefore, of 200° when compression starts is a very moderate estimate. It is never less than that, and that is the reason I have made this the minimum figure. It might easily be much more than that, especially when it is considered that in some of these engines the interior is red hot in spots. In some of them the whole wall, especially the hot bulb type, is deliberately kept red hot as an igniter. It is quite clear that any products of combustion or air in contact with that red-hot spot might easily approach or exceed a temperature of 600° before any compressing is done at all. So I make the temperatures before compression range anywhere from 200° to 600°, and there is even justification for going further.

[TO BE CONTINUED]

Nutritive Properties of Kafirin

KAFIRIN is the chief protein in kafir, one of the sorghum grains of America. It is deficient in lysine and cystine, and rats fed on a diet in which kafirin is the only protein do not grow, unless lysine is also added. The subsequent addition of cystine slightly increases the rate of growth.

Why Water Over-Fills a Tumbler*

And Floats Glass Plates and Flaky Minerals

By Will H. Coghill, Metallurgist, Bureau of Mines, and Carl O. Anderson, Fellow at University of Washington

THE epoch-making process of ore treatment known as flotation is being studied at the Pacific Northwest Station of the Bureau of Mines, in cooperation with the University of Washington. As a first step, an effort is being made to find out why some minerals are such good swimmers when placed on the plane surface of a liquid or on the curved surface of air bubbles. This study has brought interesting results.

Though the aforesaid aquatic feats of minerals have been known for many decades, they were regarded by metallurgists as an impending evil, and it is only within the last decade that the good swimmers have been encouraged as a result of which they now swim to the ore-bin via the surface of air bubbles while the poor swimmers sink and pass to the tailing pile.

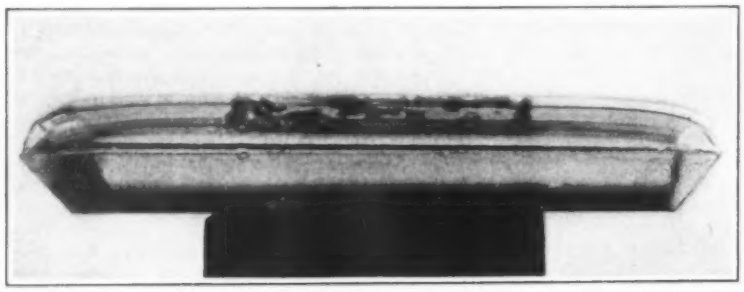

Plate 1. Lens of water on beveled glass plate. Note how edge makes barrier across which liquid is reluctant to pass

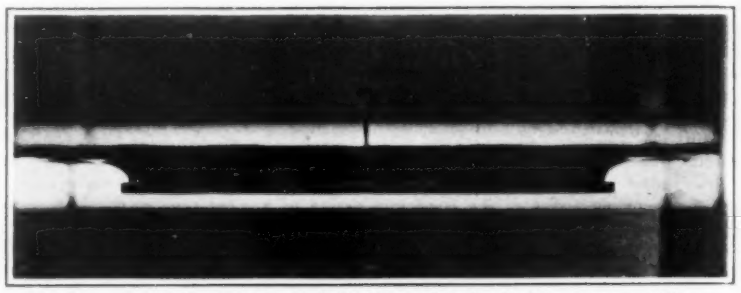

Plate 2. Grooved glass plate loaded with sand and rafted on water by "film-expansion"

The flotation process has proved a great boon to the metal mining industry. However, the hope of some that the air bubble will eventually be under such complete control of the operator that it will rise from the floatation cell and carry the mineral over the mountains to the smelter emanates from those who are too sanguine.

CAPILLARITY AND SOME OF ITS ANALOGIES

A study of the principles of flotation reveals many analogies to capillarity.

When paraffin oil forms a lense on water, when a water spider glides over a pond creating a dimple in the surface of the water with each stride, when the "proverbial needle" floats in the glass of water, when water rises in a capillary tube, and finally, when minerals float, the system of applied forces in each case is in equilibrium just as truly as are the forces which act in the members of a bridge when the weight of a train is hurled upon it.

Bridge construction is an old art and the science is therefore developed, but flotation is new and consequently undeveloped.

Though the mining engineer might have scoffed at Leslie and Laplace studying capillarity with their capillary tubes a century ago, he is now frantic in his search through their literature to gain an understanding of the flotation process so that he may combat the claims of the legal fraternity which has been subsidized by exploiters to take advantage of his ignorance in order to humbug him and steal his birthright. After all, it is the ring of the dollar that leads us to develop a science.

IMPORTANCE OF THE AMOUNT AND KIND OF SURFACE

It is an accepted principle in flotation that the ore must be crushed so fine that its surface will be enormous compared with the mass. The scientific worker naturally coordinates this principle with the well known fact that surfaces are the seat of potential energy, and that this energy always tends to modify the area so that it is a minimum. In the surface of liquids this energy is manifested by a phenomenon known as surface tension or capillarity. Gases give little or no evidence of this because their molecules are so far apart, and solids conceal it from certain methods of investigation because their molecules are fixed. Liquids, therefore, on account of the mobility of their closely packed molecules, afford the best study of capillarity.

THE FORCE OF SURFACE TENSION

A familiar surface-tension phenomenon is found in a drop of water, which reduces its surface to a minimum by forming a spherical bead on a blade of grass because of the contractile force of the surface film. This contractile force acts along the surface of the liquid and, for pure water, is known to be 73 dynes per centimeter length of surface acted upon, or about 74.5 milligrams.

This gives a relative measure of the forces entering into the equilibrium when benzene forms a film on water, when paraffin forms a beautiful lense on water, and when a very small drop of water, in spite of its great weight, floats by film-suspension on paraffin oil. This deportment of liquids may and has been predicted by a study of the equilibrium triangle of (surface tension) forces.

Since it is not possible to measure the equilibrium triangle forces when one of the liquids is replaced by a solid (no method has ever been devised to measure the tension existing between a solid and a liquid in contact), we have in the drop of water resting on paraffin oil an instructive analogy to the floatation of minerals.

AN IMPORTANT PRINCIPLE

Attention has been called to the equilibrium triangle as a means of predicting the conduct of one liquid when placed upon the surface of another, and the statement has been made that it can not be applied to determine the equilibrium of the system when a solid body meets a liquid at its free surface. Fortunately, we have an alternative which may be used in this connection. It is the angle of contact. The angle of contact bears the same relation to the system, solid+liquid+gas, as the equilibrium triangle does to the system, liquid+liquid+gas.

Before going further, therefore, the significance of the angle of contact must be fixed firmly in mind. The angle of contact is the angle at which a liquid meets a solid, that is, the angle between a solid and a line drawn tangent to the liquid where the three phases, solid, liquid and air, meet, and in a plane at right angles to this common meeting line. It is invariable for stated conditions of liquid and solid, and independent of the curvature and slope or dip of the solid.

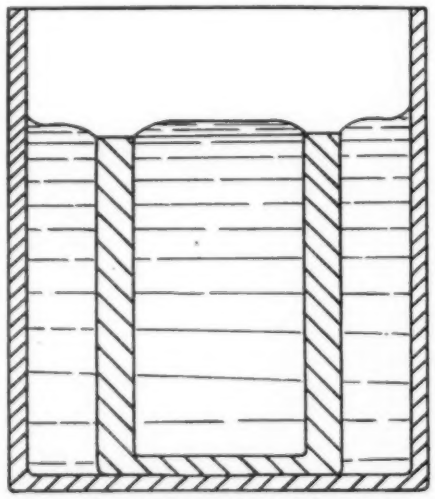

Fig. 1. Over-filled tumbler in a deep dish to which water has been added

LACK OF APPRECIATION OF COMMON PHENOMENA

Let us now see how it came about that glass, which is supposed to be so easily wetted by water that it could not possibly ride on its surface like the water-spider, was shown to be as floatable as anything imaginable when dealt with scientifically. And also let us see if we can point the way to a partial explanation of a well known phenomenon, namely, the over-filling of a tumbler with water. This will help to explain the floatability of minerals.

Many "common" phenomena are passed, not only without description and subsequent explanation, but without receiving a serious consideration, because they have not appealed to the commercial instinct; those just mentioned have recently qualified by making this appeal, so let us study them.

ONE OVER-FILLED TUMBLER

Let us now study the deportment of water in a glass tumbler. When water is poured into a tumbler it manifests its capillarity by rising against the face of the glass and making a given angle with it. This angle of contact for water advancing across the dry face of this sort of glass is, let us say, 30 degrees. A concave meniscus is the result. As water is added the surface rises and the meniscus finally meets the "top" of the tumbler and disappears. For a while, as more water is added, the liquid seems not to advance across the glass, and the surface soon curves in the opposite direction, that is, it becomes convex and the tumbler is, as we say, over-filled.

FLOATABILITY OF GLASS PREDICTED

When this over-filled tumbler is placed in a deep receptacle into which water is poured, forming a ring of water around the tumbler, the rising column shows a similar deportment toward the side and top of the tumbler. The position of the top relative to the liquid surfaces is shown in cross section in Fig. 1. This top, when viewed from above, then has the appearance of a glass ring floating in a dimple (depression) similar to those in which the water-spider and sulphide minerals float.

A consideration of the results of this observation led to the hypothesis that glass prisms are floatable. To test this hypothesis, a glass prism was cut from a thin window-pane. It was found to be floatable even after the application of a variety of cleansing processes. Successively broader and longer pieces were cut, and it was found that large plate-shaped pieces of glass of the thickness of thin windowpanes could be floated by so-called film suspension.

THE EDGE EFFECT

A reluctance of the liquid to cross the edge of the tumbler and of the floating glass plate has been noted. This brings up the question, what is an edge? An edge, as here considered, is not the mathematical line of intersection of two planes, but it is the physical curved surface of intersection of two faces; the edge of a floating glass plate across which the liquid seems to be reluctant to pass is the surface of intersection of the vertical and upper horizontal faces.

The faces of the glass prism referred to above made a "solid" angle of 90 degrees with each other. Does the reluctance of the liquid to cross this edge vary with the said "solid angle"?

In order to answer this question, a series of beveled glass plates were made with solid angles ranging from 20 to 160 degrees. Each was placed in a horizontal position, water was slowly added at the center of the dry upper surface, and the height was observed by means of a cathetometer. The water first formed a flat drop the height of which gave the measure of the angle at which it met the dry solid surface (the angle of contact). While water was added the liquid advanced to the edge maintaining a constant height, but at the edge it apparently ceased to advance and in turn developed in height until it finally broke over the edge and a certain portion of it ran to waste.

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A photograph of the water resting on one of these beveled plate-glass plates and about to break over the edge appears in Plate 1. The depth of the liquid in the picture is 0.46 centimeters though it was only 0.27 centimeters while advancing across the face. The glass has an actual thickness of 0.48 centimeters; the magnification is about three diameters.

Though at first this "point of breaking" seemed to be controlled by the magnitude of the solid angle, *i. e.*, the angle between the horizontal and inclined face which met to form the edge over which the water broke, a further study resulted in the following analysis: While the water advanced across the horizontal plane dry surface of the glass plate, it manifested its capillarity by meeting the plate at the contact angle. This angle is fixed and invariable for a given condition of the solid and liquid. When it meets the edge it seems to be reluctant to cross because it has encountered a curved surface. This reluctance is more apparent than real because the edge is narrow and changes direction rapidly. But at all times the liquid makes a given angle with a plane which is tangent to this surface along the line where the three phases meet. The addition of water develops the liquid profile as is shown by the increasing thickness of the layer. When the liquid has crossed the edge, it meets the other plane surface, then it breaks because there is no longer a change of direction of solid surface to permit a further development of the profile with its increasing head of water.

In short, it was found that the maximum height at which a lense of water would stand on such a glass depended upon the dip or pitch of the face which the liquid meets after crossing the edge; and it is this dip (and the constancy of the angle of contact), and not the solid angle that is the basis of the explanation.

OVER-FILLING DESCRIBED

We are now in a position to analyze the over-filling of a tumbler, and see what causes the liquid to break over when it has attained a certain height.

Water advancing across the clean glass has an angle of contact of about 30 degrees. When it comes to the "top" it meets an edge which is in reality a curved surface of intersection of the vertical and horizontal faces. Since this edge is very narrow, it changes direction rapidly but the liquid at all times must make a given angle with that direction. Thus, the liquid arches up without an apparent advance while crossing the edge. When it finally reaches a height sufficient for it to make the given angle of contact with the horizontal face, it passes across it and meets the outer edge. This outer edge is also a curved surface across which the liquid seems to be reluctant to pass for the same reason as stated before. While water is added, the head increases while the water advances across the edge to the outer vertical face where a further advance would not encounter a changing dip of the solid to correspond to the head of water. Here it breaks over. The accompanying diagram Fig. 2, shows the profile of the liquid meeting the inner edge of the tumbler, and also in a position where it is about to break over the outer edge.

APPLICATION OF THE ACQUIRED KNOWLEDGE

The study of water on the beveled plates led to the mathematical design of a groove around a circular glass plate forming a re-entrant angle which made it so floatable that a glass plate which was 7.7 centimeters in diameter and 0.16 centimeters thick could be loaded with 10 grams of sand before sinking.

A photograph (actual size) of a loaded plate rafted on water in a square glass box is shown in Plate 2. The hook which shows above the surface of the water was glued to the center of the plate and used to launch the raft.

Anyone who desires to make this novelty should get what is known as single strength B windowpane and have a cut-glass worker grind a groove around the periphery similar to that indicated in Fig. 3. The solid angle D should be equal to the contact angle; then the maximum possible depth of dimple will be 0.54 centimeters, and the hydrostatic head acting upward on the plate will obviously be 0.54 grams per square centimeter of plate surface. It follows from the above ratio that if the glass has a surface of infinite area it makes a barge of infinite tonnage capacity. Practically, however, there are two decidedly limiting factors; first, large liquid surfaces are not sufficiently tranquil, and, second, it is difficult to grind a groove which will fulfill the specifications. As for the latter difficulty a circular plate is the easiest to prepare because sharp turns can be avoided. We have been quite successful, however, with a glass plate 3½ inches broad and 8 inches long. The ends are pointed like those of a boat and the points have to be paraffined because the grooves can not be cut there.

This makes the old phenomenon of the floating needle seem insignificant. The difference in degree of floatability is of the same order as the difference between an art with science fully developed and one where science is ignored. Theoretically, a solid with an edge designed properly is as floatable when the angle at which the liquid meets the solid is so small as one degree as it is when the angle is larger.

An analysis to determine the forces which make up the equilibrium in such a remarkabe system reveals that the upward forces are two in number, namely, the upward component of the surface-tension film, and the upward force due to the head of water acting on the body. The downward force is the weight of the body plus the live load.

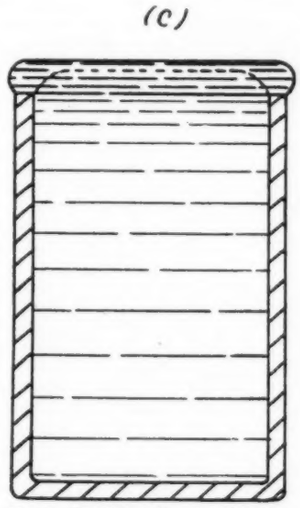


Fig. 2. Liquid profiles meeting the respective inner and outer edges of a tumbler

The greatest possible depth of dimple as stated above is 0.54 centimeters. This has been shown by a curve developed mathematically by one of us (A), the discussion of which constitutes a part of a thesis for a degree in engineering in the College of Mines, University of Washington.

Though it is scarcely feasible to advise the metallurgists to grind specially designed edges on the minerals to make them floatable, yet the study of this principle is advantageous; the mill solution is reluctant to cross the edge of

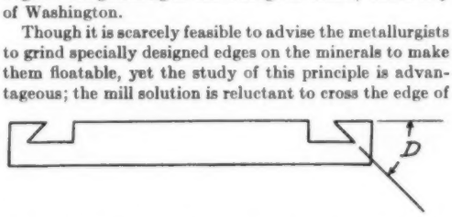


Fig. 3. Detail of groove which makes an edge that forms an efficient liquid barrier

floatable minerals, and the floatability increases with the area of the face along whose edges the three phases meet. When the mineral is too heavy to float, the profile of the dimple is developed so that it meets the face at an angle greater than the contact angle, and the liquid consequently passes across the face, and the mineral sinks. After all, the principle of the so-called film-suspension of minerals is closely related to the principle of Archimedes (any body immersed in a liquid must lose a weight equal to the weight of the displaced liquid) because it depends mainly upon the amount of water displaced; an edge makes a barrier along which the liquid forms a wall instead of flowing over the top of the mineral. The barrier vanishes only when the contact angle is zero, and only then is the mineral non-floatable. Though this does not solve the commercial problem, for, at best, it only gives the key, it is safe to predict that when a sufficient number of facts about capillarity have been acquired they can be built into a science of flotation.

Before the advent of the flotation process the metallurgist stood over his concentrating table with a club, as it were, to prevent the flaky minerals from floating. Though this property of flaky minerals has been commonly known for a long while, the explanation has been wanting. It is now obvious. It is based on the aforesaid edge effect, and we conclude that for a given mass the floatability of a mineral (and of the glass plate) increases with the area of the face along whose edges the three phases meet. The buoyant effect of a given head of water depends entirely upon the area of the face exposed to the air and is therefore independent of the shape of this face. With large faces the upward pull of the surface-tension film may be neglected, but with small faces it is a factor; and it follows that with small faces of various shapes, the solid with an oblong face exposed to the air is most floatable.

Standardization of Chemical Stoneware

STONEWARE pressure vessels (montejus, acid-eggs, and vacuum receivers), should as far as possible be spherical, flattened curves being avoided. A maximum wall-thickness of 2¼ inches is suggested, several small vessels being preferred to one larger one. Such vessels should be sunk in wooden boxes filled with sand. An armour of cast iron, steel, or lead should be avoided, its use giving rise to a false sense of security. For a spherical vessel, the theoretical wall-thickness required is $W=\frac{dp}{2U}$, where W=the wall-thickness in ins., *d*=the internal diameter in ins., *p*=the pressure in lb. per sq. in., and U=the tensile strength of the material. A margin of safety of 2 is regarded as sufficient, *i. e.*, the actual wall-thickness should be twice the theoretical value. Illustrations showing the relative dimensions of the various parts are given.

For large montejus, egg-ended cylinders of the same internal diameter and over-all height as the spherical ones, but with double the capacity, are suggested. The use of thin necks for liquid inlets and outlets on heavy vessels is condemned, a square boss into which is ground a standard pipe with a standard taper being preferable. In the boss are two longitudinal holes; a bolt is passed through each of these holes and these bolts serve to keep in position four eye-bolts passing through the bolt holes in the iron armature of the vessel. Maximum sizes for bosses used for montejus are likewise suggested.

Storage and transport jars should not exceed 2 tons capacity. Suggestions are made as to the thickness of the walls and other dimensions. The bottoms of the jars should be slightly arched inwards. Outlets should be the same as for montejus. To prevent the vessels from sweating, they may be filled with a strong solution of sodium silicate, and after a week or more the solution discharged and the vessel treated with strong acid. The diameter of cylindrical jars should be chosen so that the dies used for making large stoneware pipes or towers may be used. Socketed pipes are suitable for fumes or gases under low pressures, but not for liquids. The pipes used for corrosive fumes should be of the best stoneware, vitrified throughout, with thin walls. The jointing material should be soft and should always remain semi-plastic to facilitate alterations and repairs. The socket should be provided with an asbestos ring slightly less in diameter than the inside diameter of the socket and of slightly larger bore than the pipe; this ring acts as a cushion and forms a good base for the cement. When very hot gases are to be conveyed, care must be taken to prevent the pipes being subjected to sudden changes in temperature. Water-cooling should not be applied to pipes at a temperature above 110° C. Suggested dimensions for all the standard sizes of pipes and bends are given.

Condensing and reaction towers should be of the best material, vitrified as fully as possible and salt-glazed. All fume inlet and outlet sockets should be of ample size and should not impede draught. The bottom of the lowest piece in a tower should be arched inwards. Filling-material should not rest on the arched bottom but should be carried by the sides and by a perforated plate (with square holes) in each section. Each section should be supported by a wooden framework. The liquor outlet should be of the boss type as described for "montejus." For towers of large diameter the perforated plates should be in three parts. The plates should always rest on a thick asbestos cord and not directly of the supporting ledges. The perforations should be so arranged that any cross-section along a diameter of the plate will show a sufficient proportion of solid material to provide the requisite strength for carrying the filling material. An average of 50 per cent of perforations in plates up to 3 feet diameter is suggested, with a smaller percentage for larger sizes. The covers of towers should be domed and should contain both the liquor inlet and the fume outlet.

The expression "stoneware" should be restricted to dense, acid-resisting material used in chemical plant, the term "earthenware" being used for more porous bodies. Stoneware may be regarded as a form of porcelain and should resemble the latter in texture, vitrification, non-porosity, independence of glaze (except for appearance), resistance to chemical corrosion and changes of temperature.

No single natural clay will produce an ideal chemical stoneware, but many British clays can be satisfactorily blended with other materials. Glazed fireclay should not be used for chemical stoneware except under scientific control, as its body is essentially porous and hence too much reliance must be placed on the glaze. Economy in manufacture should be sought in a proper arrangement of the kilns and in protecting them from the weather.—Note in *Jour. Soc. Chem. Ind.* on a paper by H. Nielson and J. R. Garrow in *Chem. Trade Jour.*

A Home-Made Telescope*

A Simple and Practical Instrument For Amateur Observers

Vera M. Gushee

MANY who enjoy studying the wonders of the sky would doubtless find telescope-making a most fascinating occupation. Granted that the necessary parts are obtained in advance, it requires no great amount of technical skill or mechanical ingenuity to construct a small, inexpensive telescope well adapted for simple astronomical observations and capable of affording a great deal of pleasure and instruction. Any one who is interested in an experiment of this sort may find explicit directions in the references quoted at the end of this article. I saw at Smith College Observatory a small home-made telescope with an object-glass one and one-half inches in diameter and of about thirty inches focal length. This was used as a model, with some changes in the details of construction, especially in the style of mounting. Such an instrument, if carefully put together, is almost sure to be a source of great interest and delight for the amateur observer and may even prove useful in at least one field of scientific research, that is, in the observation of variable stars.

The first problem which has to be met when one has such a project in view is the question of obtaining the necessary material with which to work. The lenses are the only parts which cannot be produced by the novice, but since they constitute the one essential feature of a telescope, it is first of all desirable to ascertain how they can be secured. My lenses were purchased from an establishment in Brooklyn, N. Y., at a cost of $2.82 for the set. The tubing which is to be used as a mounting for the lenses can be readily formed by pasting thick sheets of paper together over a wooden roller. Mailing tubes are just the thing if they can be procured in the right sizes. Five tubes of different dimensions are needed, ranging from the smallest, about an inch in diameter and intended for the eyepiece, to a short tube of larger diameter than the rest, called a dew cap, made to slip over one end of the long main tube so as to protect the object glass when in place. This is the most important of the lenses, since it forms the image of the distant object, which is then magnified by the lenses of the eye-piece.

After ordering the lenses, and while awaiting their arrival, the tubes were made ready to receive them. First of all, there was the painting, black on the inner, and any desired color on the outer surface. As soon as this was dry they were fitted one into another according to directions. Paper collars were attached to the sheath-tube, which was thus made to fit snugly inside the longer one. Next came the draw tube, which was covered with velvet so as to slide easily back and forth within the sheath tube for the purpose of focussing. To the casual observer the telescope might seem complete at this point, but as yet it was only a toy, a "make-believe" affair which would do very well to look *at*, but not to look *through*.

With the arrival of the four precious pieces of glass, which were carefully wrapped in tissue paper and packed in cotton, my enthusiasm for telescopes suddenly increased by leaps and bounds. Although approximate values for the focal length are given in the specifications, they should be determined more exactly for the particular lenses at hand. The method in brief consists in projecting the sun's image, formed by the lens, on a piece of card-board or paper, preferably yellow in color, moving the latter back and forth until the image appears at its brightest and then measuring the distance between the card and lens. When several independent and accordant readings are obtained in this way, the mean of the series gives a satisfactory result.

This experiment proved comparatively simple where the object glass was concerned. This lens, which is one and one-half inches in diameter, has a focal length slightly less than thirty inches. It is composed of two parts loosely fitted together, a double-convex crown-glass lens, and a plano-convex flint-glass lens. Although it has to be handled very cautiously to guard against injuring the highly polished surface, it does not require such delicate measurements as the two smaller lenses for the eyepiece. This is because, when mounted, its distance from the eyepiece may be changed at will by moving the draw-tube in and out in the process of focussing. But the other lenses had to be permanently mounted with the distance between them equal to one-half the sum of their focal lengths. It seemed wise, therefore, to determine these values with as much precision as possible. The size of these lenses presented a new difficulty. The smallest is not more than one-fourth of an inch in diameter and has a focal length of only three-fourths of an inch, approximately. Some sort of contrivance was necessary to hold the lens and card steady while measurements of its focal length were being made. It would never do to hold them in the fingers, although with an assistant this method worked well enough in the case of the object glass, where less accuracy was required.

In order to provide for this need a simple apparatus was devised consisting of a support for the lens (made of ivory soap), a ruler with a centimeter scale and a piece of card-board with a slit cut into one edge so as to make it slide over the scale. The soap made an excellent holder, for it could be whittled easily into any desired shape so as to sit nicely astride the ruler, while a groove of the right size carved into the top held the lens in a vertical position. With the ruler pointed toward the sun and the card properly adjusted, the distance of the image formed by the lens could be read directly from the scale. A series of readings taken in this way seem to be quite trustworthy.

And yet was there not some means of verifying these results, which differed in one case by one-fourth of an inch from the value specified for the lens? A distant and prominent object on the earth may serve as well as the sun for an image. We selected a church tower outlined clearly against the sky and most conveniently placed for our purposes. Its image formed on the screen by even the tiniest lens was a perfect miniature representation of the original, only up-side down. Finding the place where it appeared most distinct we noted its distance from the lens which in each case corresponded very closely to the values previously determined. The slight difference in focus for the image of a terrestrial object was inappreciable, as it lay within the unavoidable errors of measurement.

In all these experiments our make-shift apparatus proved so satisfactory that I could not resist substituting a yard stick for the short centimeter scale and testing the object glass by this more convenient and refined method. It is probable, though, as already explained, that so far as the actual construction of the telescope was concerned such precaution was unnecessary.

The next step was to mount the lenses before any thing should happen to them. I gathered from different parts of the house all the necessary paraphernalia and spread it out upon the kitchen table. Besides the lenses and the tubes it consisted of a rather varied assortment, brown paper and tissue paper, an old kid glove, glue, scissors, a sharp knife, blackened card-board, shellac, and wood alcohol. The use of each of these articles will soon become apparent. The tube for the eyepiece had, first of all, to be cut down to the right length, which it will be remembered equals one-half the sum of the focal lengths of the two eye lenses. Two circular diaphragms with holes in the center were made out of the blackened card-board. One of these was glued inside the tube according to directions, to cut off light coming from the edge of the field, the other was used as a mounting for the tiniest lens, which was cemented over the opening. Then this diaphragm and the larger lens were fastened securely one at each end of the tube by means of a little shellac. A strip of tissue paper pasted neatly over the tube and fitted around the edges of the lenses served to hold the parts together, but it was not thick or durable enough to make a suitable covering. The old kid glove was just the thing that was needed. I cut out a good piece of the undressed kid and pasted it smoothly over the paper. This gave the finishing touch to the eye-piece which, it must be confessed, I viewed with considerable satisfaction.

It seemed that now the most painstaking part of the task was completed. But I had not yet dealt with the object glass. At this point the directions read as follows: "Have ready a strip of tissue paper, just the width of the thickness of the lenses at the edges; gum this on one side, and holding the two lenses together, wind the strip around the edges. When this is dry take a strip of brown paper one and one-fourth inches wide and with paste form a short tube or cell around the object glass, using (say) five thicknesses.

Although this sounds comparatively simple, patience and care are also required in large measure, for, in order to keep the lens free from particles of lint and dust and glue, which spread easily from the inner layer of the cell, I found that it was necessary to follow out the process above described not once only, but many times. So far I have omitted to mention the necessity of cleaning the lenses, but it is an important detail especially in the case of the objective. The smaller lenses were simply dipped in the alcohol and then rubbed with tissue paper before mounting, but the objective requires more careful treatment. To clean this lens wads of cotton soaked in alcohol were pressed gently against the surface *without rubbing* and as before, soft tissue paper was used for drying and polishing.

When the objective, bright and shiny and with no extraneous glue on its surface, was at last provided with a collar of the right thickness, it was carefully inserted into the object end of the telescope at right angles to the sides of the tube. This was first made about two inches shorter than the focal length of the objective so that the image would fall outside the main tube. A velvet cap was provided later which would slip over the dew-cap and protect the objective when not in use.

The telescope itself was now ready to be mounted, for some sort of support is essential if it is to be used at all advantageously. This part of the instrument consisted of a neat wooden standard about a foot high and provided with a motion in azimuth and altitude. The telescope lies in a trough-like arrangement at the top and is held in place with an ordinary strap. When it is pointed in any desired direction a turn of the thumb-screw on one side of the support holds it in position, while allowing for a slight motion in order to keep an object in the field of view. The model which was used in making this mounting is described in "Popular Telescopic Astronomy." In a great many ways it has proved exceptionally convenient.

The day on which our telescope was completed and mounted ready for use, was bright and fair and gave promise of a clear evening. But we did not wait for the sun to sink below the horizon before testing the results of our workmanship. Although the telescope was not meant for terrestrial observations and consequently showed everything inverted, it was possible nevertheless to gain some degree of satisfaction by pointing it toward distant objects on the horizon and noting the sharpness of outline in the images produced as well as the magnifying power of the eyepiece.

By these means my anxiety was partially relieved, but the real test was yet to come; not on that first evening, however, for a thick mist enveloped the sky, so that no satisfactory observing could be done. The next night was favorable. Jupiter shone out clear and bright and I lost no time in directing my "optik tube," not unlike the first which bore that name, toward his shining orb. Soon a large curious disk appeared in the field of view, but where were Galileo's four satellites? Not realizing at first that the focus was entirely wrong, I nevertheless experimented with the draw tube, pushing it in and out until the image became much smaller and brighter and three tiny points of light were revealed, two on one side of the disk and one on the other. The fourth satellite I discovered later, hugging close to the planet's disk and almost hidden in its reflected rays.

The moon, which was in last quarter, rising about ten o'clock in the evening, was to furnish the next most important test. The telescope was already clamped to the window sill on the east side of the house when the edge of the moon appeared above the line of hill tops along the eastern horizon. Very shortly all of the lighted portion was visible and I focussed the telescope upon it. A wealth of detail was immediately disclosed; low level plains contrasted with rugged and broken mountain ridges, and countless circular formations resembling the volcanic craters of the earth, crowded closely together and in places superimposed one upon the other, offering a great variety of detail. Many interesting features stood out boldly along the terminator, which is the boundary between day and night on the moon. Most conspicuous was a long bright line jutting out from the lighted portion into the blackness beyond. It was the chain of the Appenines which still retained the light of the setting sun. One hour sufficed to identify (with the help of a moon map), over fifteen objects—"seas," mountains and craters—and then the possibilities were far from being exhausted. In fact each observation of the moon taken since that time has revealed new feature brought out by closer study, aided by the varying effects of light and shade.

Other more formal tests of the optical properties of a telescope are also desirable. Some of these were made in connection with the preceding observations, others were undertaken as an object in themselves. They have reference to the "squaring" of the objective, spherical and chromatic aberration, magnifying power, and diameter of the field of view.

One of the first tests applied to my small telescope concerned the mounting of the objective. It is important that this lens be set squarely in the main tube, that is,

*From *Popular Astronomy*.

perpendicular to the optical axis, otherwise images which should be round will appear elliptical and wrong impressions will consequently be produced. The test for spherical aberration also has to do with the form of the image. An instrument is defective in this respect if the light, instead of being concentrated into a well-formed image, appears scattered in the field of view. The image of a bright star out of focus should show well defined concentric circles of light. Chromatic aberration, as its derivation indicates, refers to color effects about an image. If the moon is examined through the telescope certain colors will be visible around the edge of the disk; usually blue and orange predominate. These are caused by the unequal refraction of different light rays. This defect, which was very marked in the early telescopes, is for the most part eliminated by the achromatic lens, but not entirely. Even the best lenses produce objectionable colors in some degree but the effect should be at a minimum if the telescope is to be called satisfactory.

All the above tests applied to our little one and one-half inch lens yielded very fair results. The test for spherical aberration was especially favorable, for the image of Arcturus out of focus suggested at once a cross-section of a regular shaped tree trunk where the rings denoting its age show conspicuously.

In order to determine the magnifying power of our telescope, a very simple but entirely satisfactory method is the following: having "set" for infinite focus in advance, that is, having determined at night the position of the draw tube which produces the best stellar image, we direct the telescope toward the sky in the daytime. Then holding the head at some distance from the eyepiece a small bright circle is seen surrounded by a dark ring. This bright circle, an image of the object glass seen in the eyepiece, is called the emergent pencil of light and its diameter can be easily measured by means of a small instrument called a dynamometer, or a home-made scale such as is described in Byrd's Laboratory Manual, section 20. The magnifying power is found by dividing the diameter of the object glass by the diameter obtained by measurement. Using the latter device I found that the mean of five series of measurements made on five different days gave .068 inches. Combining this with the mean of seven measurements with the dynamometer, my adopted value for the diameter of the emergent pencil of light is .065, which gives for the magnifying power of my telescope 23 diameters.

Another preliminary observation, which is closely related to the preceding, is to determine more exactly the diameter of the field of view in time units which are easily reducible to minutes and seconds of arc. A knowledge of this value is often very helpful in later observations and may be ascertained as follows: A star (preferably near the meridian in the south), is watched as it crosses the field of view and an assistant with a watch notes the instants when the observer calls "time" as the star enters and leaves the field, that is at the beginning and end of the transit. If the star chosen is not on or near the equator, the resulting interval must be reduced to the equator by multiplying the observed time by the cosine of the star's declination. These methods of testing the telescope are typical and not exhaustive. They show what may be done by the person who intends to make the most intelligent use of his instrument.

Many of the observations possible for the common two and one-half-inch portable telescopes are also well adapted to this less pretentious type of instrument which, though lacking the advantages of a larger objective and more stable mounting, compensates for these deficiencies by offering a simple, effective substitute, easily and quickly handled and therefore more available for use by those who observe for recreation than a larger more elaborately designed model.

The one and one-half inch telescope described represents not more than $4 in actual cost and a few hours pleasurably and profitably spent. Such an instrument will not only meet the needs of many amateur observers but will prove especially helpful to all who are beginning the study of Astronomy.

References: Byrd's "Laboratory Manual"—Appendix; Fowler's "Popular Telescopic Astronomy"; Proctor's "Half hours With a Telescope"; McKready's "Beginners Star Book."

A Kashmir Barrage of Hail

By William Beebe

In battle we use such similes as, a storm of bullets, a rain of shells, but the strength of this comparison lies usually in the thoughtless acceptance of the figure of speech, rather than in any actual similarity. Once or twice in my life I have experienced natural storms which, in intensity and power of destruction, equalled any temporary hell which man, with the aid of gas or high explosive, has been able to achieve.

A month ago in Trafalgar Square, London, where there was literally a hail of shrapnel from the British anti-aircraft guns, there came to mind the most terrible hail-storm I have ever experienced, on the borderland between Garhwal and Kashmir, in the western Himalayas.

I was camped in a wonderful hanging valley with the last outpost dâk bungalow snuggled in the center, surrounded by a host of tall spired silver firs and deodars. Spring was at its height, and the open spaces were almost paved with a mass of white strawberry blossoms, with roses and pink-flowered raspberries in the underbrush. In the dense shade of the deodars were lilies-of-the-valley and great banks of maiden's hair fern. Birds were courting or building, or, as in the case of an impeyan pheasant which I had discovered, were already sitting on eggs.

One day I surprised a troop of great gray langur monkeys in the act of robbing this nest, which fortunately I had already photographed. As I came along the slope, the marauders swung past me, old and young hurling themselves recklessly from spire to spire. Tree after tree shook and bent as in a terrific gale of wind; small dry branches crashed and splintered; cones, needles, and twigs rained to the ground as the troop rushed by. The uproar which these banderlogs create has usually but little effect upon the lesser creatures of the forest. They well know the danger as well as the limitations of the four-handed folk.

But when this troop passed, quiet did not settle down. There was no wind, no movement of the needles. Even the ferns hung motionless. But there was sinister undercurrent more potent than noise of elements. Something was about to happen, and not concerning any one animal, or in any one glade. The birds were restless and their notes were those of anxiety. Pheasants called in a way which they should not have done except in early morning; small creatures rustled here and there among the leaves. I picked up my gun and walked toward camp.

I crossed two bridges. Still no wind, but a sound of restless life everywhere, a tense uneasiness. And then came the climax, swiftly, mercilessly. From the Tibetan snow-peaks in the distance billowed a breath of cold air—icy, unfriendly—and a dark cloud swept across the sun. The mist grew thicker and closed down. The birds and forest creatures became silent as death, and for as long as two minutes the silence was oppressive. Then in the distance, dimly through the fog, the trees bent and straightened, the mist yellowed and a drop of rain fell. Finally, came a sound as strange as any in the world, the noise of ice falling on flowers and leaves, a mitrailleuse volley of hail such as only the great Himalayas know.

Lashed by the ice, our horses whinnied with pain and fright, and although wild mountain ponies, crowded close to us beneath the shelter of the dâk. They pushed in out of the downpour, and while they had been exposed only to the first, rather light, fall, yet their coats were covered with welts as if from blows of finely divided thongs of a whip.

After fifteen minutes of hail such as we are familiar with in the States, the stones grew larger and the downpour more furious, until the crash of falling ice dominated all other sounds. The floor of the valley became white and the hail-stones—now much larger than marbles—bounced and leaped high after their impact with the ground.

Leaves and whole fans of spruce needles were torn away and covered the bruised blossoms of the forest slopes. The air was a screen of straight lines, breaking near the ground into a maze of dancing, splintering crystal balls.

Before the bombardment ended I put out my hand, with the result that one stone struck my thumb and lamed it for three days. Without warning, the sun came out and made of the storm a translucent tapestry, through which the broken foliage was dimly visible. It was so wonderful, so unlike anything I had ever seen, that I forgot momentarily the terrible damage—the shredded foliage, the host of stricken nestlings and creatures which had not found a safe retreat. When the last missile had fallen I wondered whether the most hardy tenant of the forest had survived. And nature in mockery of my ignorance, having ceased her cruel torrent, sent out the frailest of frail butterflies, flickering its copper wings before me in the sun.

I found others which had not been so fortunate, and in one spot, beneath a thin-leaved bush were thirty-eight good-sized butterflies, with wings only slightly torn, but all killed and partly buried beneath a mass of jellied hail-stones. About fifty per cent of the nests which I had under observation were destroyed, but some were preserved by overhanging banks. This was the case with a very beautiful babbler's nest, which with its three eggs was quite unharmed, sheltered in a niche, in the side of a steep grassy bank.

Not far away, behind a bit of loosened deodar bark, was a most delicate nest of a rufus-capped titmouse, with three dead and one unharmed young bird. Two big hail-stones had crashed down, one being wedged a few inches above the nest, while the other had fallen with full force into the mass of moss and pheasant feathers, and then slipped over the edge. The forlorn youngster, balancing himself on a bit of stick, looked as if life held out no hope of any kind, but at the chirp of his parents, he opened his eyes, and when I left him he had his mouth wide agape, begging as only infant birds can.

I found traces of many other tragedies, one of the most unexpected being the bodies of two giant flying squirrels. These splendid rodents, which weigh as much as five pounds and are sometimes over three feet in length, are not uncommonly seen in the dusk of evening, volplaning from trunk to trunk in these mighty evergreen forests. These had apparently been sleeping in a half hollowed out space behind some bark which had been torn away, and the ice had stunned and killed them before they could escape. Lizards were flattened on rocks and logs, and the total destruction of animal life must have been very great. Certainly no creature of small size had any chance if exposed to the full fury of the ice. A chicken in an open crate was so injured that we had to kill it.

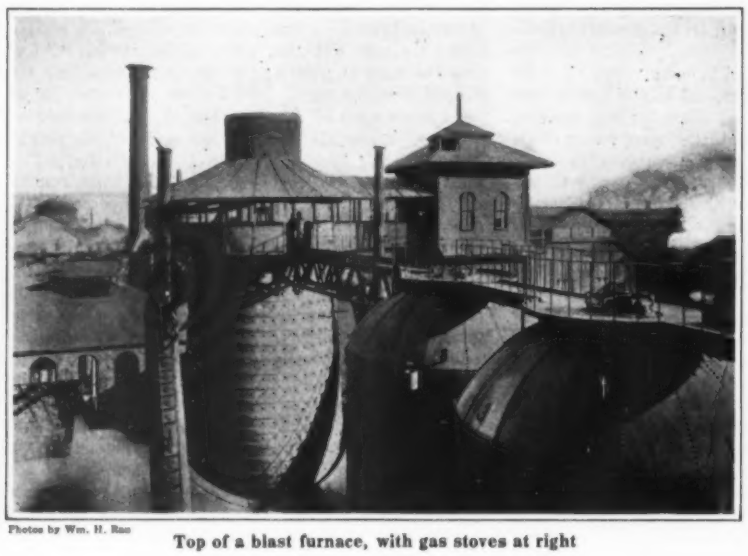
Taken altogether, this Kashmir storm was the most severe one I have ever witnessed, and my servants would have had a bad time of it if they had not been able to reinforce the sloping walls of their tent and so keep under cover. As it was, great rents were torn in the canvas and the men were pretty badly frightened by the time it was all over.—*Bulletin* of the New York Zoological Society.

The Gibraltar Straits Tunnel

Interest has lately revived in the scheme for a tunnel beneath the Straits of Gibraltar, which has, like that for a railway link between England and France, made an appeal to engineers for a generation or more. Some of the technical aspects of the project have been under discussion before the French Society of Civil Engineers, and it does not appear to be thought that there are any abnormal difficulties on the engineering side. Owing to the depth of water and character of the sea bed and the underlying strata, it would be necessary to construct such a tunnel at a depth, it is believed, of some 840 metres; and the length between Tarifa, the suggested point of departure on the Spanish side of the Straits, and either of the alternative points of emergency on the Morocco coast, would be about 15½ miles. It is assumed by the advocates of the scheme that the cost of construction would not exceed £10,000,000, but necessary port improvements would call for the expenditure of an additional £4,000,000. There can be no doubt that the linking of the European and African railway systems would give a great stimulus to French and Spanish trade, and on the assumption that the tunnel beneath the Straits of Dover is constructed, the tunnel would provide over the Trans-African railway a through route between England and South Africa. The scheme now put forward by M. Henri Bressler does not differ in its essential aspects from that planned by Berlier twenty years ago; but it is felt that the case for the tunnel has been strengthened in the interval, and it is believed that the capital could now be found without seeking any financial aid from either the French or Spanish Government.—*Engineering Supplement of the London Times.*

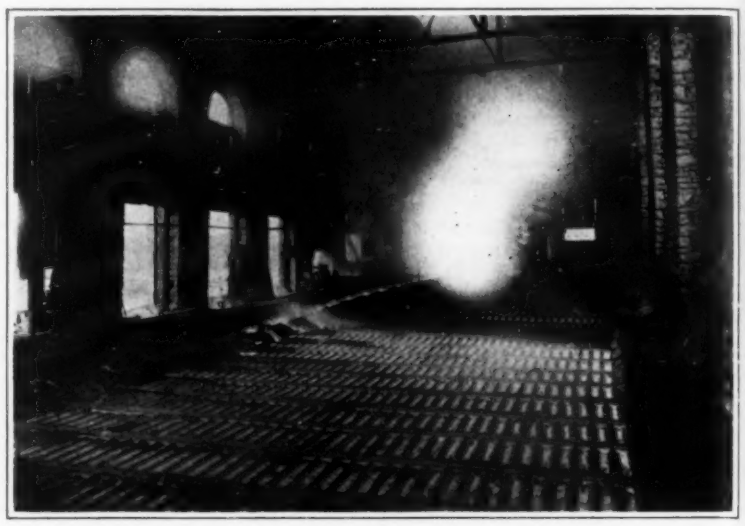
Pearl Shell Industry in Australia

The pearl shell industry is largely carried on in Australia, especially in Queensland and other parts of the country. The pearl oyster is found along the northern and western coasts of Australia for a distance of over 2,000 miles. On the north coast the pearls taken out are of small size, but the shells themselves are an important commercial product. The Shark Bay pearl industry is carried on both for pearls and shells, usually with the aid of diving apparatus. In tropical Queensland, pearl shell diving is actively pursued and is by far the most important of the fishing industries. In connection with it we may also mention that tortoise shell is obtained on these same coasts. Two distinct species of mother of pearl are exported from western Australia, the principal trade being done with the large shell (*Meleagrina margaritifera*), whose distribution is limited to tropical waters. It is used for the larger manufactured articles such as knife and fork handles, large buttons and inlaid work. The largest and finest pearls are obtained from this shell. The second species is the one known commercially as the Shark Bay variety (*Meleagrina imbricata*), which is smaller and used chiefly for the manufacture of small buttons. The exports of pearl shell from Australia during the year ending June 1916 were value at nearly $5,000,000, which is about 13 per cent increase over the preceding year.



Photos by Wm. H. Rau

Top of a blast furnace, with gas stoves at right



Casting bed, where pig iron is made

Big Things in Steel

Some Things Seen in a Plant Where Big Guns Are Made

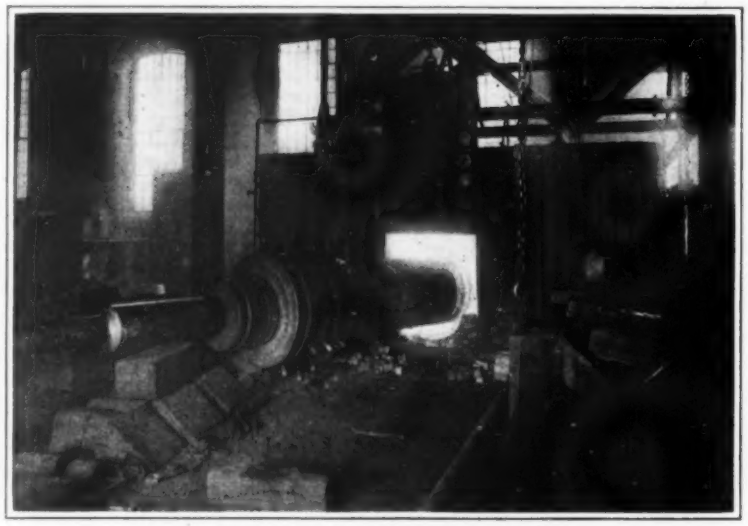
THE accompanying illustrations show some of the details of the plant and of the operations in a large steel works where big guns and heavy armor plate are made, but it is difficult for the layman to get a real conception of the magnitude of the operations, for in work of this character the masses handled are figured in tons where the pound is the standard in ordinary shops.

One of the pictures shows the top of a huge blast furnace, over a hundred feet tall, in which the crude iron ore is melted down and converted into metallic iron, and alongside the furnace are seen two of the stoves in which a portion of the gases generated in the furnace are burned to heat the air for the blast in the big furnace. Large quantities of combustible gas are generated in the blast furnace in the process of melting iron, and besides that used in the stoves, other portions are utilized for heating steam boilers and as fuel for the large internal combustion engines that operate the blowers which furnish the blast to the furnace. Thus it will be seen that the blast furnace performs a four-fold purpose; it melts the ore, heats the air required for the blast, furnishes power for the blowing engines and makes steam for other power purposes.

From the blast furnace the molten iron may be run out into thousands of molds made in the sand floor of a large building, to form the well known pig iron; but this is an old process now little used except where the metal is to be shipped for use in ordinary iron foundries, and even here the modern method of making pig iron is to run the metal into a series of iron molds that travel on an endless chain past the blast furnace, each being filled in turn, and a short distance further on the still red hot pigs are dumped from the mold, which, after being cooled, returns to repeat the operation. In the large modern steel plants still another method of dealing with the crude metal is employed. If the metal is first run into pigs a large amount of fuel is required to again melt it in the operation of converting the iron into steel, and in order to save this and to save time, it is now customary to run the melted crude iron directly from the blast furnace into the already hot furnaces in which the iron is converted into steel.

From the steel making furnaces the refined metal is run into molds that form ingots, of a size suitable for the subsequent manufacturing operations intended; but owing to the fact that in pouring the metal into the molds a considerable quantity of air is carried in with the metal, and also because gases are generated in the metal itself, "blow holes" and "pipes" are apt to be formed in the ingot. These are cavities in the metal, more generally found at the top of the ingot, and result in defects in the material produced. To overcome this difficulty, and to reduce the possibility of unsound ingots as much as possible, a process of "fluid compression" is adopted in some cases, especially in making ingots intended for big guns, and the large illustration on the front page of this issue shows the apparatus. The molten steel is poured into a massive iron mold, which is at once run under the great hydraulic press shown in the photograph. The mold is placed on the platen of the press, which is supported on the piston, while a plunger that corresponds in size with the internal diameter of the mold is rigidly held by the massive cross-head. As the mold, with its contents, is raised by the pressure applied in the hydraulic cylinder, sunk in the bottom of the pit, the plunger is forced upon the fluid metal in the mold, and the tremendous pressure exerted squeezes out much of the contained air and gases, and compacts the metal, with the result that the formation of the above mentioned cavities and defects in an ingot are very largely prevented. Such cavities as may remain are confined to the extreme upper end of the ingot, and only a short piece has to be cut off to obtain a solid and homogeneous mass of steel. The press shown exerts a pressure of 7,000 tons.

If the ingot is to be made into a gun it is then put into a great lathe or a boring mill, which forms a hole longitudinally through the ingot. Then the ingot is again heated in a gas furnace, and forged down to as near the required size and shape as possible. Formerly this forging was done under an immense hammer, but it was found that in working the metal in this way the force resulting from the blows of the hammers did not reach the interior of the mass, and as the working the metal has an important effect on its subsequent quality, other methods were sought for, and this has led to the adoption of hydraulic forging presses, one with a capacity of 5,000 tons being shown in one of the illustrations, although very much more powerful presses are now in common use. In the making of heavy armor plate the same processes are employed, but of course, these do not have to be bored, as in the case of gun forgings.



Heating an ingot for a big gun before forging

Another one of the accompanying photographs shows a portion of a shop where the machine work on big guns is performed, and it will be noted that a powerful traveling crane is a prominent feature; and this is a necessity where such heavy pieces have to be handled and moved from one place to another. Great cranes of various kinds are prominent features of shops of this kind, and are to be found in every part of the works, for mere man-power would be of little avail in moving the great masses of metal, sometimes weighing as much as 150 tons, and it is always interesting to watch the ease and accuracy with which cyclopean pieces of metal are quickly swung about.

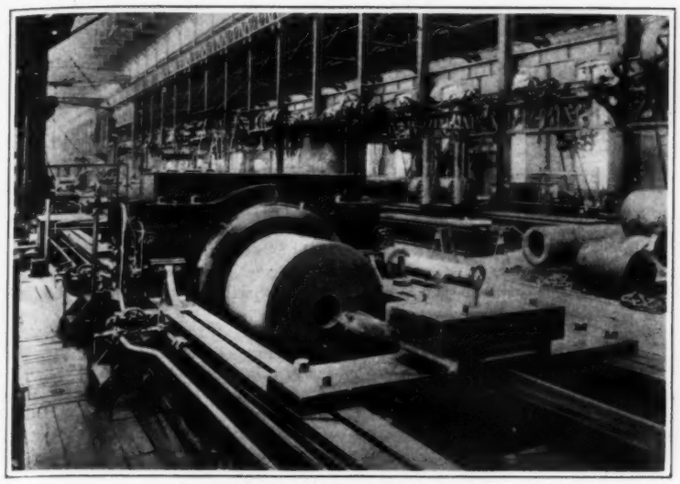
A modern steel works is one of the most spectacular and impressive institutions of the modern manufacturing world, and the engineering, mechanical and technical ability devoted to its development make such a plant one of the wonders of the world.

Marginal Fog in Photographic Negatives

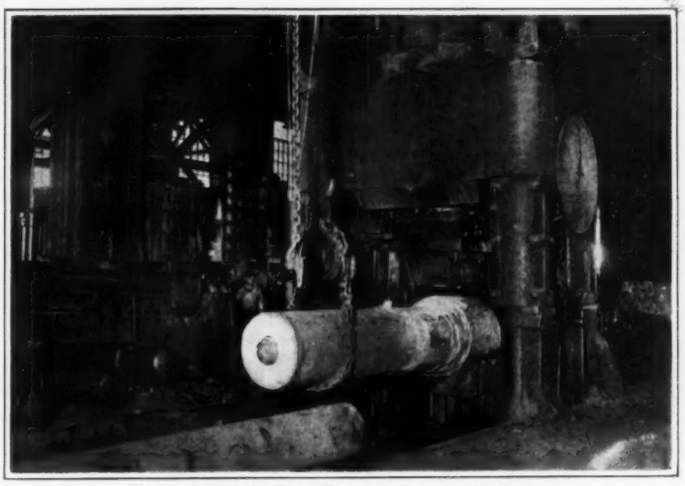
IT sometimes happens that the excessive taking of precautions is the cause of defects in negatives which would never have occurred at all to a more happy-go-lucky worker. We had an instance of this the other day in some negatives which were shown to us with the suggestion that they were due to stale plates as evidenced by the narrow band of fog along the edges. We did not agree, because in the first place the fog had not the dichroic appearance which is usually associated with staleness of the emulsion, and in the second place it occurred only on two sides of the plate. While it is admittedly possible that the packing of plates may be such that they suffer on two edges only, it is rare for this to be the case, and we sought other causes for the phenomenon. We found it in our friend's camera, a heavily built landscape instrument with the back frame of rather more than ordinary thickness. A glance at the interior showed that the portions of this back frame adjacent to the plate, when the latter was exposed to the lens, were about as shiny as they well could be. Inquiry showed that it was this worker's practice to rub the entire inner woodwork of the camera with a duster before taking it out for use, with the result that what originally was a dead black surface had been rubbed up to quite a respectable polish, and one which, according to the subject, was capable of reflecting a narrow band of light upon the edge of the plate. Reflections from the inner woodwork of a camera are responsible for more markings on plates than many perhaps realize; and one of the things which may well be done every few months is to touch over wood or metal surfaces which can possibly come within the field of the lens with a little dead black. —*Brit. Jour. of Photography.*

An Educated Ape

THE New York Zoological Society has acquired a highly educated female chimpanzee that is quite human in her attainments. She dines skilfully at a table and finishes off her repast by smoking a cigarette. Evidently she is qualified to enter our most exclusive social circles.



Boring the breach piece of a 16-inch gun



Forging a breach piece of a gun in a powerful press

The Fabricated Ship

AT the launching of the "Agawam," the first fabricated steel ship, President Henry R. Carse of the Submarine Boat Corporation, that built the ship, made the following statement that tells in a few words what the "fabricated ship" is:

"The launching of the 'Agawam' celebrated a new era in the construction of steel ships.

"The 'Agawam' is the first of 150 vessels, all of the same standardized type, from designs of Theodore E. Ferris, to be built of commercial steel plates and shapes along lines evolved by bridge builders in conjunction with naval architects, and thus enabling us to call upon the structural metal workers of the country.

"The parts are fabricated in bridge and tank shops throughout the country east of the Mississippi River and assembled at this plant.

"Ninety-five per cent of the work in forming the parts entering into the hull of this vessel and punching rivet holes is done at shops widely separated, from drawings furnished by this company, and these drawings have been of such exactitude and the work has been so carefully performed by the different bridge shops that when they are brought together at this yard they fit perfectly, and the ship, as you see, is absolutely fair.

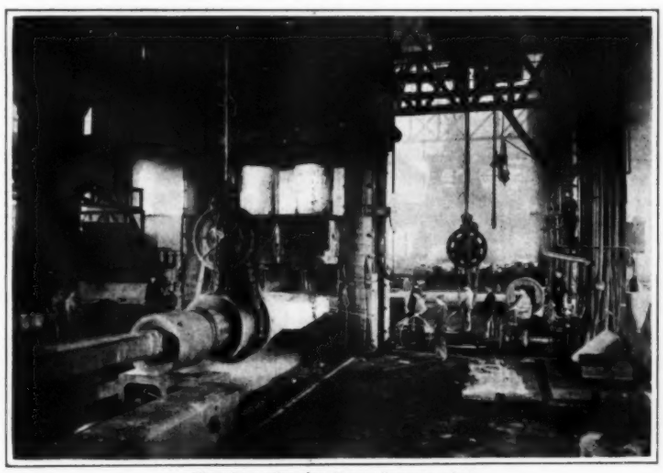
"The construction of the hull of this vessel requires the driving of over 400,000 rivets, and by our method more than one-quarter of these rivets are driven at the distant shops, the different parts being brought to the yard in sections as large as can be transported on the railroads. Each part is numbered and lettered, and as they are shaped perfectly, all that is necessary is to place them in position, bolt them and finally fasten them with rivets.

"Standardized fabrication to this extent has never before been attempted in the shipbuilding industry, and this development has been brought about only by the urgent need for ships and the necessity for securing them by some new method, for old methods could not replace the loss of shipping caused by the ravages of the German submarines.

"This company had finished in the fall of 1916 the manufacturing of 550 submarine chasers for the British Admiralty ahead of contract time under the direction of Vice-President Sutphen, and the experience gained in the fabrication of the hulls of those boats and the purchasing of machinery and other accessories, which were shipped to Montreal and Quebec and there assembled into the finished boats, led Mr. Sutphen to study the subject of applying the same method to the fabrication and assembling of steel cargo vessels from the only available material, commercial plates and shapes, as the mills of this country were not equipped to produce ship plates and shapes in sufficient quantity.

"Our contract was signed September 14th, 1917, and since that time, through the most severe winter of a generation, we have converted a marsh waste into what you see before you in plant and ships.

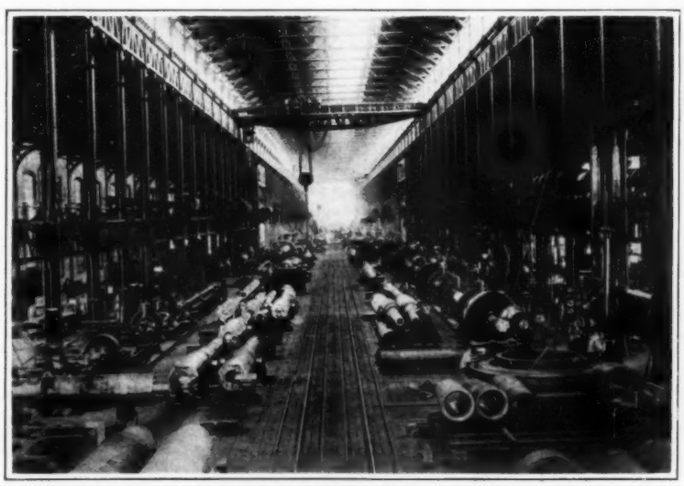
"We appreciate the great task we have undertaken of delivering two or three complete vessels ready for sea every week and we need all the encouragement possible to maintain us in the stress of our great effort. We want to feel that we can call upon all for such assistance as you can furnish us in doing this work for the nation and for its allies, for the spiritual side of this work is fully as important to us all as the merely material side."



Forging a heavy piece of armor plate

Dried Milks

THE report deals with the history, methods of preparation, and distribution of dried milk, its physical and chemical characters, its bacteriology, and more particularly its use in infant feeding. It is considered that dried milk is a valuable food and one which possesses certain special advantages; it is easy to transport, keeps for a reasonable period of time without developing an unpleasant flavor, and is economical. Dried milk is not germ-free, but the number of bacteria present is relatively very small as compared with ordinary milk, especially in those varieties of dried milk which have been prepared by passing milk over rollers heated above 100° C.; there is no tendency toward multiplication of the number of bacteria when the milk is kept. The pathogenic bacteria which may have been contained in the original milk are either destroyed or reduced in number and rendered less virulent by the drying process. Dried milk prepared from a mixture of separated milk and an emulsion of some vegetable oil such as cottonseed oil, forms a suitable food for some infants but not for all.—*British Food Report.*



Scene in a big gun shop

Stain Which Tones

WE continue every now and again to receive prints and postcards showing stained patches of a slaty-blue color, the cause of which as a rule our correspondents imagine to lie in the hypoalum toning process. The toning bath, however, is not really at fault, but, by its toning action, is merely disclosing a fault which existed latent in the print. While opinions may differ, our own, which is based upon a very large number of different cases, is that these slate-blue stains arise from imperfect fixation of the original prints. In some instances the bluish patches have straight sides, indicating that incomplete fixation has been brought about by one print lying upon another in the fixing bath. However it may be caused, it is pretty clear that there are left in the print patches of silver compound which are tonable in the hypoalum bath and do tone in that bath, often yielding a deposit of very considerable intensity. As we have several times pointed out, the preventive is in a photographer's own hands. If prints are passed through two fixing baths in succession it will almost invariably be found that the occurrence of these stains ceases altogether. It is, of course, necessary that the two baths, and particularly the second, should be maintained in active working condition. As a matter of practice it is a good plan to discard No. 1 as soon as it has reasonably done its work, to replace it by No. 2, and to pour out a fresh lot for the second bath.—*Brit. Jour. of Photography.*

Peat Fuel in Canada

THE high cost of coal in Canada again brings up the question of the manufacture of fuel from the immense beds of peat in various provinces. Extensive experiments were made some years ago by Dr. Haanel, of the Department of Mines, but they were not followed up. The fuel crisis brought about by the war has forced the Scandinavian countries to go anew into peat manufacture. The output of peat fuel in Sweden last year was 22,500 tons, but this year it will exceed 100,000 tons. Denmark, which produced 200,000 tons in 1916, will have an output this year of over half million tons. In Norway there are 217 peat machines which cost about $13,500 each, can be worked by two men, and will turn out 35 to 45 tons per day.—*Can. Chem. J.*

Electrolysis Mitigation—II

Discussion of Causes and Methods of Regulation[1]

[Concluded from Scientific American Supplement, No. 2220, Page 47, July 20, 1918]

GENERAL SCOPE OF REGULATIONS

(*a*) *Voltage Limitations.*—From the foregoing it will appear that one of the most essential things to be incorporated in electrolysis regulations is an appropriate limitation of the potential drops in the railway track network, or in the earth and pipe systems, and that such limits should be applied in the case of railway tracks to both the overall potential drops between remote parts of the system and also to potential gradients in relatively short portions of the track network, the former being necessary to guard against the accumulation of large potential differences which might occur even with low gradients, provided the feeding distances are very long, and the latter to prevent the very rapid change in the voltage of the track in any portion of the system which might give rise to bad local conditions even though the overall potentials were kept comparatively small.

In fixing voltage limits for regulation it is desirable to specify the manner in which the voltages are measured and potential drops computed. In determining the potential gradients the voltage drop on a distance of 1,000 feet is generally better than a much shorter length. This length is long enough to give a fair average condition over a considerable length of track, and at the same time short enough to prevent any serious accumulation of potential difference at any point, provided the limits mentioned above are substantially complied with. In calculating the potential gradient it is best to measure the distance in an air line between the terminal points, provided the region crossed by this line is occupied by pipe networks; but if the pipe networks follow an indirect course, measurements should be made by way of the pipes.

(*b*) *Potential Wires.*—In order to facilitate the determination at any time of the voltage drop, it is very important that permanent potential wires be installed running from a suitable terminal board at some central point and connected to the tracks or pipes at those points between which potential measurements are to be made. These should always be run to the more outlying points and also to the point in the system of approximately lowest potential so that the maximum overall potential drops can be directly measured. It is desirable also in most cases to have some wires run to intermediate points, so that any high potential drop that may be observed can be approximately localized by measurements with the potential wires. Such wires may either be especially installed for the purpose of taking potential measurements, or wires for this purpose may be leased from a telephone company. When satisfactory terms can be arranged, the leasing of wires is preferable, since the maintenance of these wires would, in general, be less than of special wires run separately for this purpose.

In view of the fact that the purpose of the potential wires is not primarily for the protection of the pipe systems but rather to supply information to all parties concerned as to the conditions which exist, it seems preferable that the expense of installing and maintaining or of leasing such potential wires should be borne jointly by all of the utility companies directly concerned in the electrolysis mitigation problem. If this were done, the cost to any particular company would be practically negligible and it would remove any material objection which the railway company might otherwise have to the installation of such potential wires. Graphic voltmeters should also be provided for measuring and recording the potential differences required.

(*c*) *Connections Between Tracks and Pipes.*—Metallic connections between underground metallic structures and the street railway tracks should never be permitted at any point where the pipes might become negative to the tracks and such ties deliver current into the pipe system. Such connections are sometimes advocated as a means of reducing voltage drops in the negative return, but the objections to such procedure are too obvious to be discussed here. It is not desirable in general to prohibit all metallic connections between pipes and railway negative return in the regions near the power stations, although in general in city systems such connections are not desirable, except in the case of lead cable systems where properly restricted drainage may be used. There are, however, special cases in which it might be desirable to install such ties on pipe systems, and this should not be entirely prohibited by the regulations.

(*d*) *Interconnection of Tracks.*—Wherever two or more railway systems operate in the same territory it is of the greatest importance that the tracks should be electrically connected together at all intersections and such interconnection should be required by regulations. In special cases where tracks, either of the same or different railway lines, parallel each other for a considerable distance, such as half a mile or more, and where the tracks are only a block or so apart, it is important that occasional crossties between the lines be installed to prevent wide fluctuations of voltage between them. This would be a special provision designed to meet local conditions rather than a general rule.

(*e*) *Track Maintenance.*—If the voltage drops in the tracks be limited by regulation and if a sufficient number of potential wires are installed not only to the remote points of the system, but also to intermediate points so that the potential gradients on practically all sections of the track of lengths from 1,000 to 3,000 feet can be readily measured, it would not appear desirable to superpose on this any additional regulation in regard to track maintenance, leaving that matter entirely to the railway company. If, however, potential wires are connected only to the remote portions of the network, they would not give sufficient data in regard to electrolysis conditions at intermediate points, and in such cases it would be desirable to have some sort of regulation covering track maintenance. This might take the form of a rule requiring periodic tests and reports of the condition of the track bonding, and definitions regarding what may be considered a good or bad bond.

Practice in regard to the latter point varies considerably in this country, but in general where the resistance of a joint (including 3 feet of rail), exceeds the resistance of a length of from 6 to 10 feet of rail the joint is considered defective. Cross bonding between tracks should also be required at frequent intervals.

The best practice in this country at the present time calls for cross bonds at intervals of from 200 to 500 feet of track, according to traffic conditions, and bonding at shorter distances is required where the traffic is heaviest. Such bonds should be designed to carry the maximum current to which they can be subjected in use.

(*f*) *Exemptions.*—Where railway lines operate in a territory remote from pipe systems exemptions from stringent regulations should generally be made. The German regulations exempt entirely railway lines which operate at a distance exceeding 200 meters (650 feet) from any pipe systems. Such an exemption undoubtedly involves no danger to the underground structures. Where the railway line is so constructed that the rails are practically insulated from the earth, such, for example, as a railway line on a private right of way on which the rails are set up on wooden ties entirely out of contact with the earth, exemption from rigorous voltage regulations regarding track potentials should also be made.

(*g*) *Insulated Negative Feeders.*—If the regulations prescribe certain specific and definite voltage limitations that must be complied with, it will not be best to specify the manner in which such regulations are to be met. In order, however, to make it readily possible to further improve conditions at a later date, if such improvement should be found necessary, and to accomplish this without any appreciable extra cost to the railway companies, it would be well to require that in any future construction wherever negative feeders are installed at all they should be installed as insulated feeders in such a way that they may, when necessary, be converted into what has been defined in this paper as an insulated negative feeder system. The insulation of negative feeders in this way is practically no more expensive than the installation of uninsulated feeders, so that no hardship would be imposed on the railway company by such requirements; on the other hand, in case future experience showed it to be necessary to still further reduce voltage drops, it would be a decided advantage to the railway company to have the feeders installed in this way.

In considering the subject of regulations for the mitigation of electrolysis, it should be borne in mind that while the railway companies are chiefly responsible for reducing stray currents to as low values as are commercially practicable, the owners of underground utilities also must be considered to have certain responsibilities, particularly in so far as new construction work is concerned in territory already occupied by electric railways.

There are a number of things that pipe and cable owning companies can do at a very slight additional expense that will go very far to reduce electrolysis trouble, provided such measures are taken at the time the pipes or cables are installed. For example, in new work or repairs, pipe lines should be laid as far as possible from railway tracks. Where the density of service connections is sufficient to justify the use of two mains, one on each side of the street, these should be laid down in order to eliminate the necessity for running services across under the railway tracks. This is quite common practice in many places where the utilities are highly developed, and it could frequently be extended in many instances with considerable improvement in local electrolysis conditions. Further, in laying new mains or repairing old ones, it is very simple and inexpensive to install a sufficient number of insulating joints largely to reduce stray currents in that portion of the pipe network, and such construction should be encouraged in every practicable way.

Wherever it is necessary to run service pipes across the street under railway tracks, care should be taken either to lay them as far as practicable below the tracks or else to provide substantial insulation between the service pipe and the track or between the service and the main by means of insulating joints; the latter will generally be found cheapest and most effective.

In view of the fact that excessive drainage of current from one pipe system may set up a condition of serious danger in a neighboring system, measures should be taken to so restrict the drainage of current from any one underground metallic structure that it will not be maintained at a potential sufficiently lower than surrounding structures to cause any serious injury thereto.

Where regulations governing electrolysis mitigation are necessary, they should preferably be enacted and administered by State authority, where the necessary administrative machinery is available. In the absence of such administrative authority, however, the cities in which the utilities operate, should take the initiative.

It is in the highest degree desirable that regulations be made as few and as simple as possible, to the end that the various utilities concerned may enjoy the greatest freedom of action consistent with safety to the underground structures.

The present apparent necessity for regulations governing this subject is due to the lack of cooperation in the past between the railway companies and the owners of underground utilities. If the various interests concerned, and particularly the railway companies, would show a greater disposition than they have commonly done to meet the issue, and instead of practically ignoring the subject, as has been too often done, would treat the matter as one of the engineering problems connected with the operation of street railways, the need for stringent regulations would be largely eliminated with advantage to all concerned. In the absence of such a far-sighted policy, however, compulsory and perhaps more or less burdensome regulations will become inevitable.

[1]From a Technological Paper issued by the U. S. Bureau of Standards.

Some General Aspects of Evaporation and Drying

Direct evaporation under atmospheric pressure or in a vacuum is used where: the amount of liquor to be evaporated is so small that it would not pay to have a multiple effect; the boiling points are very high; the liquor deposits an encrusting material on concentration where crystals of a certain size are desired; the material to be evaporated is corrosive, or decomposes at a high temperature; the object is to recover a volatile constituent or to obtain artificially a low temperature or a sudden chill as in refrigeration processes; the liquor to be evaporated is already a concentrated solution and the product is separated as a dry film, powder, or mass of crystals. Direct vacuum evaporation (single effect) shows very little economy of steam over evaporation under atmospheric pressure and none at all if the vacuum has to be produced by steam power. Multiple-effect evaporation is used where the cost of fuel is high and the quantity of liquor to be evaporated is large. Air drying or gas drying depends upon the property of partially saturated air or gas of taking up more vapor, and it may be profitably employed in drying pulp, paper, cloth, etc.; in drying at low temperatures substances of which the internal structure must be preserved; where the final product must be obtained in a fine state of division; in drying such substances as are not affected by heat but are sticky or poor conductors of heat. The heat necessary to evaporate the water may be supplied by the air or gas itself or may be applied directly. Drying by means of radiant heat is used when it is necessary to concentrate substances that require a high temperature and when there is no suitable material of which to construct ordinary apparatus. Heat conductivity tables of physicists are of little use in practice, as the rate of heat exchange is largely increased when ebullition becomes violent owing to the rapid motion of the liquid.—H. K. Moore in *Am. Inst. Chem. Eng.*

Insects Helpful To Man

THE importance of insects in the animal world is too generally overlooked. The American Museum of Natural History, by means of interesting specimens and groups in its Hall of Insect Life, is endeavoring to familiarize the public with some of the more striking aspects of insect life and activities, especially as they affect man. Such knowledge is certainly desirable in view of the fact that of the million and more species in the animal world, the largest place is held by the insects. Perhaps their significance may be better realized from the fact that the annual loss by insects in the United States is $800,000,000, as compared with an annual fire loss of $143,600,000 and that they are directly responsible for 22 per cent of the wheat loss, 20 per cent of the fruit loss and 10 per cent of the animal products loss. As over against 7,000 deaths per year due to railroad accidents, there are 97,200 deaths each year in this country due to malaria and intestinal diseases, spread by insect carriers. And while in the whole Spanish War only 300 men were killed by Spanish bullets, 5,000 died of fly-borne diseases. Yet, in the face of these startling facts, and contrary to popular belief, the great majority of insects are either harmless or beneficial to man. For the damage by insects is done by less than one per cent of the species, and a large number of the remainder spend their lives keeping those in check. Great work in eliminating waste by insects has been done and is being done by the State experiment stations, and on a larger scale by the National Department of Entomology at Washington. But while the importance of this work and the need for it cannot be overestimated, the fact remains that we are wrong if we take the attitude that insects are an unmixed curse.

Although we are able to determine fairly accurately the damage done by insects, it is impossible to calculate the benefits they confer. It is true that certain species destroy $29,400,000 worth of fruit annually; but the remaining $147,000,000 worth owes its existence largely to the pollinating of the blossoms by insects. Practically no fruits could be formed without the aid of insects, and in the production of a harvest, insects, especially bees, dwarf into insignificance all modern implements of husbandy. It would be impossible to get a single crop of red clover without the aid of insects, and the present scarcity of bumble bees, who usually perform this service, is making itself felt in the smaller crops and lower vitality of the clover seed. Their importance in this connection was realized in Australia and the Philippine Islands, which imported bumble bees for the sake of their clover crops. Figs could not be successfully grown in this country until a fig pollinating insect was imported from the Mediterranean countries. A great majority of the beautiful flowers depend on insects for the development of their seed, only the inconspicuous ones being typically wind-pollinated.

But perhaps the most valuable beneficial insects are those which function in repressing the harmful insects by preying on them. The services of the dragon fly in this capacity are of the greatest interest and importance. This insect has long been the object of fear and dislike by human beings, owing no doubt to its fierce appearance and rapid, darting motions. Children have been terrified by the superstition that the dragon fly, "devil's darning-needle," would pierce their ears, or sew them shut. Yet the dragon fly is not only harmless to man, but is one of his best friends in that he is the deadly enemy of the mosquito—that pest that is one of the most numerous, widely distributed and persistent of the creatures that menace the health and comfort of man. So much is the dragon fly the mosquito's enemy that he is called the "mosquito-hawk"—and anyone who has watched the swift movements and cruel aspect of the dragon fly as he darts at his prey will agree that the name is well given. As both the mosquito and dragon fly are semi-aquatic, the warfare between the two begins early, the young of the dragon fly feeding on the young mosquito, just as the adult dragon fly preys on the full-grown mosquito. As serious blood maladies are known to be transmitted by the mosquito, the dragon fly's service to man is no small one. At one time, in fact, it was undertaken to breed dragon flies artificially with the purpose of exterminating the mosquito, but the plan was found impracticable and was abandoned.

Another beneficial insect is the variety of Australian beetle which was used with brilliant success to save the orange orchards of the nation. The so-called "Australian lady-beetle" was pitted against the destructive scale insect which threatened ruin to the orange industry. The beetle exterminated the scale. Parasitic wasps attack caterpillars and sting them to death, laying eggs in the dead bodies of their victims, so that their young, when hatched, may find abundant and convenient nourishment. The wheat midge, so destructive to the grain, is preyed on by several insects. Ravenous two-winged flies seize and carry it away to suck out its juices. But most powerful of its insect foes are its parasites—small, black, four-winged flies somewhat resembling ants. Their young subsist on the larvae and eggs of the midge, and live therein. As the midge increases in numbers, its enemy increases in proportion, for the numbers of the parasites depend on the amount of available nourishment. Eventually the parasite overwhelms the midge. This is illustrated by the fact that often, a year or two after an excess of midges, there is a great scarcity of the noxious insect. In the same way the army worm and frightfully destructive Hessian fly are constantly kept repressed by their parasitic foes. Human efforts to exterminate the gypsy moth have failed, and the United States Government is now importing insect parasites of the pest to aid in the war of extermination.

Many insects act as scavengers, and only one, the common house-fly, has the obnoxious habit of carrying the filth to our food.

To certain insects which feed on dead wood we are are indebted for ridding us of much refuse of a sort that would otherwise seriously accumulate.

Tales of the use of insects as food are very frequently discredited. The locust and wild honey fare on which John the Baptist is described as having lived in the wilderness has been claimed by some to have been a plant, such as is to be found in Bermuda under the name of tornela, or more popularly "locust and wild honey." On the other hand there have been earnest supporters of the theory that the manna on which the people of Israel fed was an insect excretion. While the development of agriculture and commercial facilities have rendered the use of insects as food in most cases unnecessary, in other times and under other conditions men have not despised the insect as a means of subsistence. And even today various insects are eaten and relished by men, although their relative importance as food is now of course almost negligible. In support of the original John the Baptist tradition is the fact that the locust has long been and is still eaten in Arabia, Persia and Africa. The Moors fry the insect in butter, making a favorite and staple dish. Locusts are said to be used much in Indian curries, even in Calcutta. Many of our own North American Indian tribes consumed large quantities of Rocky Mountain locusts. When these Indians were great in number, the Rocky Mountain locust was practically harmless. Now that the Indians are reduced to a mere vestige of their former numbers, and are conforming largely to our food habits, however, the locust has become a serious pest, for it eats every green leaf it can reach. A mixture of pulverized ants, grasshoppers and locusts, dried in the sun, was a delicacy with a certain tribe, while others preferred grasshoppers and crickets combined, with roasted ants as a variant. Grasshoppers were used in soup or were boiled into a tasty paste. It may come as a shock to some admirers of the ancient Greeks to learn that grasshoppers were highly prized as delicacies by Greek epicures of the time of Pericles. Among other insects which have been and are considered as of gastronomic value are caterpillars, a North American Indian delicacy; moths, a favorite in some parts of Africa; the pupae of the silk worm in China and the pupae of a South Indian silk moth. Ants, alive or roasted, are appreciated in Burmah, as by the Indians of North and South America and of the East Indies, while from reliable sources we receive assurance that the lumbermen of Maine enjoy an occasional meal of large black wood ants. In the lake region of Central Africa the natives, when short of tobacco, are fond of chewing "sweet earth"—the clay of the local anthills. The beetle is eaten in the Nile Valley, in Turkey, Lombardy, Moldavia, Java, Peru and Valachia, and is claimed to be very nutritious and fattening. In Central America the eggs of three aquatic bugs are made into little cakes and eaten. A large bug is eaten with rice in Assam, and in Nyasoland a paste of mayflies and mosquitoes arouses enthusiasm. The Mexicans manufacture a drink as strong as their pulque by infusing a tiger beetle in alcohol.

But as interesting as the use of insects for food is their employment as medicines and they are so honored by both homeopathists and allopaths. A beetle called the Spanish fly, with some of its allied species, is fairly widely used as a vesicating or blistering agent, and also forms an ingredient of many hair washes. The oil beetle, when handled, ejects from the joints of its legs a clear yellow oil, which has been used with success in Germany as a remedy for hydrophobia, and in Sweden as an ointment for rheumatic inflammation. The galls of the gall fly furnish tannin, which has strongly astringent properties. While formic acid is now artificially prepared, it was formerly obtained from ants, and employed in many ways medicinally. Insects have been variously enlisted in the treatment of toothache, earache and weak sight, to cure dropsy, and for kidney and bladder diseases, pleurisy, pericarditis, enlarged tonsils and other troubles. Cochineal is recommended by the United States Dispensatory for whooping cough and neuralgic afflictions, due to its anodine properties.

In addition we have many insect products of no small value. Most familiar are honey and wax from the bee. There is also a Chinese bug which secretes a kind of grease on various trees. This hardens into wax, and is collected, melted and purified, when it becomes white and glossy in appearance, and when mixed with oil can be made into candles. The cochineal, a scale insect living on cacti in the American tropics, besides having medicinal qualities, yields the two dyes called carmine and lake. While nowadays most dyes are chemically made, the natural dye of the cochineal is employed in coloring soldiers' uniforms, as it stands the weather better than commercial dyes. The pupae of a Mexican black fly which swarms in great quantities near Lake Texcoa are used as fertilizer. No enlargement is needed on the work of the precious silkworm—a native of China, which is now raised here also. Commercial shellac is obtained by melting "lac," the resinous substance produced by an East Indian scale insect and deposited in a crust on twigs to contain the insect and its eggs. The export value of lac from Indian ports in one year has risen as high as 33,000,000 rupees. Lac has also been used to make dyes, but while the lac industry is a growing one, the employment of lac in making dyes has probably had its day. The best lac is obtained from Bengal and the Central Provinces of India. It is also used as stiffening for hats, sealing wax, as an ingredient of lithographic ink, in electrical work and in the manufacture of gramaphone records.

The very attractive exhibits in the American Museum of Natural History demonstrate all these facts, and many others, and a visit to the Insect Hall will be well repaid by the extremely interesting and valuable information to be pleasantly acquired there. And of interest to many will be the "Field Book of Insects," prepared by Dr. F. E. Lutz, Associate Curator of the Museum's Department of Invertebrate Zoology. The book treats in a fascinating way particularly of the insects of northeastern United Statse, and aims to answer common questions.

Importance of Petroleum Products

THE average person fails to realize the importance of petroleum and its products in the ordinary routine of the world's work, yet every man, woman and child in America is dependent in some measure upon petroleum and natural gas. There is scarcely a phase of our national life in which we do not find petroleum products used—they drive our battleships, deliver our merchandise, pull our trains, heal our wounds, color our garments, smelt our ores, carry our mails, cook our meals, and increase our knowledge of the outdoor world. They illuminate the magazine we read and the book we study; they carry us home from the office, and make chewing gum for the children.

Every industry makes some use of petroleum or its products, and to list all of the uses would not be feasible here. It is sufficient to say that petroleum is essential to the commercial development of the country, and that if our supply were cut off today, our industrial progress would be brought almost to a standstill. It has been said that when petroleum is gone, electricity will take its place, but, although electricity will furnish power for our industries and lights for our homes, it will not lubricate even the machinery needed for its own generation.

The Navy is dependent on the petroleum industry not only for lubricating oils but to an increasing extent for fuel. Battleships that use oil as a fuel can carry larger armaments, and have a greater range of action than those that use coal. Petroleum is thus vital to our national defense and perhaps to our national existence.—*Yearbook of the U. S. Bureau of Mines.*

An Instructive Series of Horse Skeletons

AN American Museum exhibit of international fame is the series of horse skeletons mounted by Mr. S. H. Chubb and installed in the hall of the age of man. The series at present includes the skeletons of the draught horse at rest and in motion, the full-grown Shetland pony grazing, the Arabian stallion on the alert, and the race horse in action, all of which show a spirit and vivacity resulting from the most painstaking and exact attention to all niceties in the mechanics of bodily movement. It is now proposed to make the series more complete by the addition of the skeleton of a trotter, the distinctive American type of fast horse. In this connection Mr. Chubb recently spent three weeks at Cuba, N. Y., on the estate of Mr. Frederick B. Simpson, making a large series of photographic studies of the motions of "McKinney," a well-known trotting horse, which has been presented to the Museum by Mr. Simpson.—*The American Museum Journal.*

Radiation and the Electron—I*

New Facts Require a Revision of Classical Theories

By R. A. Millikan, Ph.D., Sc.D., Professor of Physics, University of Chicago

RECENT developments in the domain of radiation are of extraordinary interest and suggestiveness, but they lead into regions in which the physicist sees as yet but dimly—indeed, even more dimly than he thought he saw twenty years ago.

But while the beauty of a problem solved excites the admiration and yields a certain sort of satisfaction, it is after all the unsolved problem, the quest of the unknown, the struggle for the unattained, which is of most universal and most thrilling interest. I make no apologies, therefore, for presenting tonight one of the great unsolved problems of modern physics, nor for leaving it with but the vaguest of suggestions toward a solution.

The newest of the problems of physics is at the same time the oldest. For nothing is earlier in the experiences either of the child or of the race than the sensation of receiving light and heat from the sun. But how does light get to us from the sun and the stars through the empty interstellar spaces? The Greeks answered this query very simply and very satisfactorily from the standpoint of people who were content with plausible explanations but had not yet learned perpetually to question nature experimentally as to the validity or invalidity of a conclusion. They said that the sun and all radiators of light and heat must shoot off minute corpuscles whose impact upon the eye or skin produces the sensations of light and warmth.

This corpuscular theory was the generally accepted one up to 1800 A. D. It was challenged, it is true, about 1680 by the Dutch physicist, Huygens, who, starting with the observed phenomena of the transmission of water waves over the surface of a pond or of sound waves through the air, argued that light might be some vibratory disturbance transmitted by some medium which fills all interstellar space. He postulated the existence of such a medium, which was called the luminiferous or lightbearing ether.

Partly no doubt because of Newton's espousal of the corpuscular theory, the ether or wave theory gained few adherents until some facts of interference began to appear about 1800 which baffled explanation from the standpoint of the corpuscluar theory, but which were easily handled by its rival. During the nineteenth century the evidence became stronger and stronger, until by its close the corpuscular theory had been permanently eliminated for four different reasons: (1) The facts of interference were not only found inexplicable in terms of it, but they were completely predicted by the wave theory. (2) The fact that the speed of propagation of light was experimentally found to be greater in air than in water was in accord with the demands of the ether theory, but directly contrary to the demands of the wave theory. (3) Wireless waves had appeared and had been shown to be just like light waves save for wave-length, and they had been found to pass over continuously, with increasing wave-length, into static electrical fields such as could not possibly be explained from a corpuscular point of view. (4) The speed of light had been shown to be independent of the speed of the source as demanded by the ether theory and denied by the corpuscular theory.

By 1900, then, the ether theory had become apparently impregnably intrenched. A couple of years later it met with some opposition of a rather ill-considered sort, as it seems to me, from a group of extreme advocates of the relativity theory, but this theory is now commonly regarded, I think, as having no bearing whatever upon the question of the existence or non-existence of a luminiferous ether. For such an ether was called into being solely for the sake of furnishing a carrier for electromagnetic waves, and it obviously stands or falls with the existence of such waves *in vacuo*, and this has never been questioned by anyone so far as I am aware.

Up to 1903, then, the theory which looked upon an electro-magnetic wave as a disturbance which originated at some point in the ether at which an electric charge was undergoing a change in speed, and was propagated from that point outward as a spherical wave or pulse, the total energy of the disturbance being always spread uniformly over the wave front, had met with no serious question from any source. Indeed, it had been extraordinarily successful, not only in accounting for all the known facts, but in more than one instance in predicting new ones. The first difficulty appeared after the discovery of the electron and in connection with the relations of the electron to the absorption or emission of such electro-magnetic waves. It was first pointed out in 1903 by Sir J. J. Thomson in his Silliman lectures at Yale. It may be stated thus:

X-rays unquestionably pass over, or past, all but an exceedingly minute fraction, say one in a thousand billion, of the atoms contained in the space traversed without spending any energy upon them or influencing them in any observable way. But here and there they find an atom from which, as is shown directly in C. T. R. Wilson's photographs here presented on the screen, they hurl

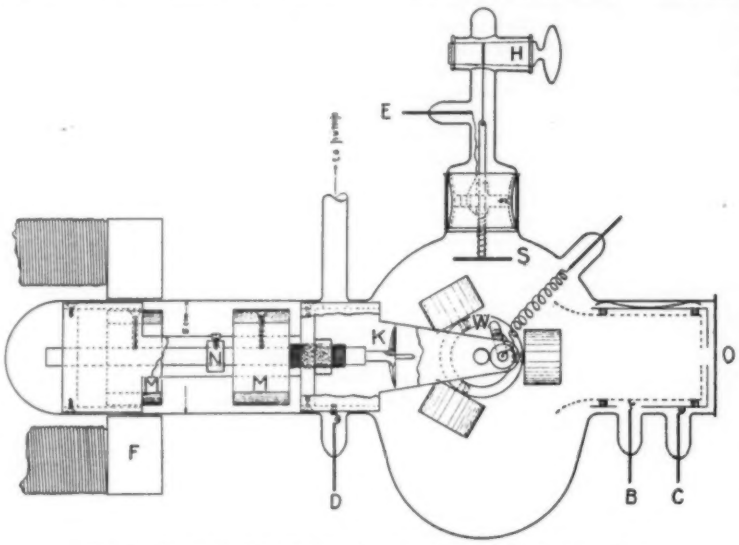


Fig. 1. Cross-section of apparatus for testing Einstein's equation

a negative electron with enormous speed. This is the most interesting and most significant characteristic of X-rays, and one which distinguishes them from the α and β-rays just as sharply as does the property of non-deviability in a magnetic field; for neither α nor β-rays ever eject electrons from the atoms through which they pass with speeds comparable with those produced by X-rays, else there would be new zigzag lines branching out from points all along the paths of the α and β-particles shown in the Wilson photographs.

But this property of X-rays introduces a serious difficulty into the ether theory. For if the electric intensity in the wave front of the X-ray is sufficient thus to hurl a corpuscle with huge energy from one particular atom, why does it not at least detach corpuscles from all of the atoms over which it passes?

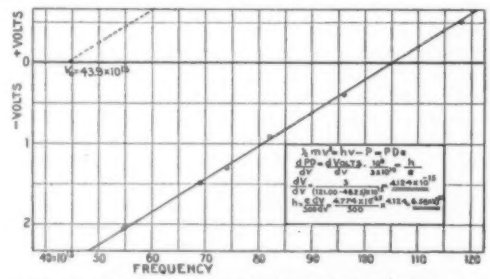


Fig. 2. Graph showing relation between energy of electric emmission and frequency of the light

Again when ultra-violet light falls on a metal it, too, like X-rays is found to eject negative electrons. This phenomenon of the emission of corpuscles under the influence of light is called the photo-electric effect. Lenard[1] first made the astonishing discovery that the energy of ejection of the corpuscle is altogether independent of the intensity of the light which causes the ejection, no matter whether this intensity is varied by varying the distance of the light or by introducing absorbing screens. I have myself[2] subjected this relation to a very precise test and found it to hold accurately. Furthermore, this sort of independence has also been established for the negative electrons emitted by both X- and γ-rays.

Facts of this sort are evidently difficult to account for on any sort of a spreading-wave theory. But it will be seen that they lend themselves to easy interpretation in terms of a corpuscular theory, for if the energy of an escaping electron comes from the absorption of a light-corpuscle, then the energy of emission of the ejected electron ought to be independent of the distance of the source, as it is found to be, and furthermore, corpuscular rays would hit but a very minute fraction of the atoms contained in the space traversed by them. This would explain, then, both the independence of the energy of emission upon intensity and the smallness of the number of atoms ionized.

In view, however, of the four sets of facts mentioned above, Thomson found it altogether impossible to go back to the old and exploded form of corpuscular theory for an explanation of the new facts as to the emission of electrons under the influence of ether waves. He accordingly attempted to reconcile these troublesome new facts with the wave theory by assuming a fibrous structure in the ether and picturing all electromagnetic energy as traveling along Faraday lines of force conceived of as actual strings extending through all space. Although this concept, which we shall call the ether-string theory, is like the corpuscular theory in that the energy, after it leaves the emitting body, remains localized in space, and, when absorbed, is absorbed as a whole, yet it is after all essentially an ether theory. For in it the speed of propagation is determined by the properties of the medium and has nothing to do with the nature or condition of the source. Thus the last three of the fatal objections to a corpuscular theory are not here encountered. As to the first one, no one has yet shown that Thomson's suggestion is reconcilable with the facts of interference, though so far as I know, neither has its irreconcilability been as yet absolutely demonstrated.

But interference aside, all is not simple and easy for Thomson's theory. For one encounters serious difficulties when he attempts to visualize the universe as an infinite cobweb whose threads never become tangled or broken however swiftly the electrical charges to which they are attached may be flying about.

Yet the boldness and the difficulties of Thomson's "ether-string" theory did not deter Einstein[3] in 1905 from making it even more radical. In order to connect up with some results to which Planck, of Berlin, had been led in studying the facts of black-body radiation, Einstein assumed that the energy emitted by any radiator not only kept together in bunches or quanta as it traveled through space, as Thomson had assumed it to do, but that a given source could emit and absorb radiant energy only in units which are all exactly equal to $h\nu$, ν being the natural frequency of the emitter and h a constant which is the same for all emitters.

I shall not attempt to present the basis for such an assumption, for, as a matter of fact, it had almost none at the time. But whatever its basis, it enabled Einstein to predict at once that the energy of emission of corpuscles under the influence of light would be governed by the equation

$$\tfrac{1}{2}mv^2 = Ve = h\nu - p \qquad (41)$$

in which $h\nu$ is the energy absorbed by the electron from the light wave or light quantum, for according to the assumption it was the whole energy contained in that quantum, p is the work necessary to get the electron out of the metal, and $\tfrac{1}{2}mv^2$ is the energy with which it leaves the surface—an energy evidently measured by the product of its charge e by the potential difference V against which it is just able to drive itself before being brought to rest.

At the time at which it was made this prediction was as bold as the hypothesis which suggested it, for at that time there were available no experiments whatever for determining anything about how the positive potential V necessary to apply to the illuminated electrode to stop the discharge of negative electrons from it under the influence of monochromatic light varied with the frequency ν of the light, or whether the quantity h to which Planck had already assigned a numerical value appeared at all in connection with photo-electric discharge. We are confronted, however, by the astonishing situation

*Presented at the meeting of the Section of Physics and Chemistry of the Franklin Institute, and republished from the Journal of the Institute by permission.

[1] *Ann. d. Phys.* (4), VIII (1902), 149.

[2] *Phys. Rev.*, II (1913), 173.

[3] *Ann. d. Phys.* (4), XVII (1905), 132; XX (1906), 199.

that after ten years of work at the Ryerson Laboratory and elsewhere in the discharge of electrons by light this equation of Einstein's seems to us to predict accurately all of the facts which have been observed.

The method which has been adopted in the Ryerson Laboratory for testing the correctness of Einstein's equation has involved the performance of so many operations upon the highly inflammable alkali metals in a vessel which was freed from the presence of all gases that it is not inappropriate to describe the present experimental arrangement as a machine-shop *in vacuo*. Fig. 1 is a drawing of a section of the apparatus which should make the necessary operations intelligible.

One of the most vital assertions made in Einstein's theory is that the kinetic energy with which monochromatic light ejects electrons from any metal is proportional to the frequency of the light, *i. e.*, if violet light is of half the wave length of red light, then the violet light should throw out the electron with twice the energy imparted to it by the red light. In order to test whether any such linear relation exists between the energy of the escaping electron and the light which throws it out it was necessary to use as wide a range of frequencies as possible. This made it necessary to use the alkali metals, sodium potassium, and lithium, for electrons are thrown from the ordinary metals only by ultra-violet light, while the alkali metals respond in this way to any waves shorter than those of the red, that is, they respond throughout practically the whole visible spectrum as well as the ultra-violet spectrum. Cast cylinders of these metals were therefore placed on the wheel *W* (Fig. 1) and fresh clean surfaces were obtained by cutting shavings from each metal in an excellent vacuum with the aid of the knife *K*, which was operated by an electromagnet *F* outside the tube. After this the freshly cut surface was turned around by another electromagnet until it was opposite the point *O* of Fig. 1 and a beam of monochromatic light from a spectrometer was let in through *O* and allowed to fall on the new surface. The energy of the electron ejected by it was measured by applying to the surface a positive potential just strong enough to prevent any of the discharged electrons from reaching the gauze cylinder opposite (shown in dotted lines) and thus communicating an observable negative charge to the quadrant electrometer which was attached to this gauze cylinder. For a complete test of the equation it was necessary also to measure the contact-electromotive force between the new surface and a test plate *S*. This was done by another electromagnet device, but for further details the original paper may be consulted.[4] Suffice it here to say that Einstein's equation demands a linear relation between the applied positive volts and the frequency of the light, and it also demands that the slope of this line should be exactly equal to $\frac{h}{e}$. Hence from this slope, since e is known, it be possible to obtain h. How perfect a linear relation is found may be seen from Fig. 2 which also shows that from the slope of this line h is found to be 6.26×10^{27}, which is as close to the value obtained by Planck from the radiation laws as is to be expected from the accuracy with which the experiments in radiation can be made. The most reliable value of h obtained from a consideration of the whole of this work is

$$h = 6.56 \times 10^{-27}$$

In the original paper will be found other tests of the Einstein equation, but the net result of all this work is to confirm in a very complete way the equation which Einstein first set up on the basis of his semi-corpuscular theory of radiant energy. And if this equation is of general validity it must certainly be regarded as one of the most fundamental and far-reaching of the equations of physics, and one which is destined to play in the future a scarcely less important rôle than Maxwell's equations have played in the past, for it must govern the transformation of all short-wave-length electromagnetic energy into heat energy.

In spite of the credentials which have just been presented for Einstein's equation, we are confronted with the extraordinary situation that the semi-corpuscular theory out of which Einstein got his equation seems to be wholly untenable and has in fact been pretty generally abandoned, though Sir J. J. Thomson[5] and a few others[6] seem still to adhere to some form of ether-string theory, that is, to some form of theory in which the energy remains localized in space instead of spreading over the entire wave front.

Two very potent objections, however, may be urged against all forms of ether-string theory of which Einstein's is a particular modification. The first is that no one has ever yet been able to show that such a theory can predict any one of the facts of interference. The second is that there is direct positive evidence against the view that the ether possesses a fibrous structure. For if a static electrical field has a fibrous structure, as postulated by any form of ether-string theory, "each unit of positive electricity being the origin and each unit of negative electricity the termination of a Faraday tube,"[7] then the force acting on one single electron between the plates of an air condenser cannot possibly vary *continuously* with the potential difference between the plates. Now in the oil-drop experiments[8] we actually study the behavior in such an electric field of one single, isolated electron and we find, over the widest limits, exact proportionality between the field strength and the force acting on the electron as measured by the velocity with which the oil drop to which it is attached is dragged through the air.

When we maintain the field constant and vary the charge on the drop, the granular structure of electricity is proved by the discontinuous changes in the velocity, but when we maintain the charge constant and vary the field the lack of discontinuous change in the velocity disproves the contention of a fibrous structure in the field, unless the assumption be made that there are an enormous number of ether strings ending in one electron. Such an assumption takes all the virtue out of an ether-string theory.

Despite then the apparently complete success of the Einstein equation, the physical theory of which it was designed to be the symbolic expression is found so untenable that Einstein himself, I believe, no longer holds to it, and we are in the position of having built a very perfect structure and then knocked out entirely the underpinning without causing the building to fall. It stands complete and apparently well tested, but without any visible means of support. These supports must obviously exist, and the most fascinating problem of modern physics is to find them. Experiment has outrun theory, or, better, guided by erroneous theory, it has discovered relationships which seem to be of the greatest interest and importance, but the reasons for them are as yet not at all understood.

[TO BE CONTINUED]

[4] *Phys. Rev.*, VII (1916), 362.

[5] *Proc. Phys. Soc. of London*, XXVII (December 15th, 1914), 105.

[6] "Modern Electrical Theory," Cambridge, University Press, 1913, p. 248.

[7] J. J. Thomson, "Electricity [illegible] p. 9.

[8] *Phys. Rev.*, II (1913), 109.

The Physiology of the Retina

A PAPER on the above subject was read before the Illuminating Engineering Society by Prof. W. M. Bayliss.

The first portion of the paper was devoted to a discussion of the perception of light by the eye. There are three chief processes: (1) The production of an image by the dioptric system of the eye; (2) the excitation thereby, on the layer of the retina containing the rods and cones, of a photo-chemical change which in turn acts upon the terminations of the optic nerve fibers, which transmit a series of nerve-impulses; and (3) the distribution of these impulses to the complex system of nerve cells in the brain, where the consciousness of illuminated objects is developed. The sensation is essentially an affair of the brain—the "cerebral analyzers." The nature of the nerve-impulse is obscure. It has much about it that resembles an electric current. But whatever its nature it appears to be substantially the same for all nerves, *e. g.*, both visual and auditory. The sensitiveness of the retina is exceedingly great, being estimated to be about 3,000 times that of the most rapid photographic plate. For the purpose of increasing the stimulus there are present in many sense organs devices analogous to electrical relays. In the eye this extraneous energy is provided by chemical oxidations in the living cells of the sense organs.

The only satisfactory explanation of the behavior of the retina is based on stimulation through the intermediary of chemical action. At present only one photo-chemical substance, the visual purple, has been identified in the eye, but practically nothing is known as to its chemical constitution. The fact that apparently visual purple did not occur in the central region of the retina, where visual acuteness is greatest, presented a difficulty, but according to Edridge Green it flows into this area from adjacent parts of the retina. The lecturer presented three curves illustrating respectively the amount of energy required to produce the sensation of light, and action on and absorption by the visual purple throughout the spectrum. The close resemblance between these curves shows that the visual purple is closely associated with the process of percep[illegible] Visual purple is bleached by light but reapp[illegible]ess. The chemical process is apparently r[illegible]n as light ceases, and when a luminous imp[illegible]eived a progressive change occurs until eq[illegible]tablished. This explains the fact that an a[illegible]erval is required for a luminous sensation to [illegible] value, while the reaction that occurs after [illegible]ulse is removed would account for the posi[illegible]ive after-images.

Other information is obtained on this point by studying the electrical changes which accompany the action of light, and diagrams, illustrating the growth and decay of such retinal currents in the retinæ of pigeons, etc., were presented by the lecturer. The exact functions of the rods and cones have been the subject of much discussion, and the decision is evidently one of great difficulty.

In the latter part of the paper the lecturer discussed the bearing of a knowledge of the retina on various problems in illuminating engineering. There seems to be a general impression that vision is assisted when the illuminated area viewed by the fovea is surrounded by an area of moderate brightness, so that the peripheral regions of the retina are also stimulated. The sensation of glare, due to excessive contrast, is well recognized, but is difficult to explain completely on physiological grounds; when the exposure to excessive brightness is very severe or prolonged detectable damage to the cell structures can be made out. While it would be premature to say that a physiological basis for a numerical value for the "glare-limit" has been established, the suggestion that, for complete comfort of vision, a ratio of brightness not exceeding 100: 1 should be adopted seems to be a reasonable one. It has been shown, however, that the effect of lateral illumination in causing discomfort, and its influence on acuteness of vision, are distinct things. It is even possible for an adjacent bright light to cause a temporary gain in acuteness of vision, though possibly at the expense of discomfort and ultimate strain. Glare is closely associated with the effect of the adaptation of the eye. A source which can be viewed without discomfort in a high illumination may be a source of glare when the eye is more or less adapted to darkness.

Another point of great interest to lighting engineers is the determination of a method of testing fatigue of the eye due to inadequate illumination. The matter, is, however, complicated by the effect of many extraneous factors, which it is difficult to dissociate from the effect of light. Little is known regarding the effects of light or different colors on the eye, though here again the quality which is most conducive to fatigue is not necessarily that least favorable to great acuteness of vision. On many practical points such as the effect of inadequate illumination in causing defects of eyesight, especially in school children, and its influence on the vision of workers in factories, fuller statistical information is required. On such points the cooperation of medical officers of health would be very useful.—*The Electrtcian.*

Botulism in London

ABOUT twenty-five cases of a disease believed to be botulism have recently occurred in London and Sheffield. After an incubation period of from twelve to twenty-four hours the disease sets in acutely with paralysis of the internal and external muscles of the eye, dilation of the pupil, vomiting, arrest usually of the salivary secretion, difficulty of swallowing and loss of voice, and depression of the heart's action, which may cause a fatal issue. The condition is due to a poison found in food by the action of a bacillus, the *B. botulinus*, which chiefly occurs in tinned food, ham and sausages; from the last named the name is derived (Latin, *botulus*—a sausage). So far the *B. botulinus* has not been isolated in connection with the present series of cases, and until this is accomplished its exact nature must remain somewhat doubtful.—*Nature.*

Currents in the Upper Air

The behavior of the streaks or trains left by large meteors supplies abundant evidence as to the rapid motion of the atmosphere at its outer limits. The diversity of direction, as well as the rate of velocity of these upper winds is remarkable; in fact, hurricane speed would appear to be quite a common feature among them. It is true that the data are not of sufficiently accurate character to allow very exact deductions to be drawn, but there is no doubt as to the general correctness of the results. In some instances the observations have been as complete as they have been precise, and these corroborate in a very satisfactory manner the average values obtained from more uncertain or incomplete records.

The long-enduring streaks of swift fireballs, like the Perseids and Leonids, are usually about fifty-five or sixty miles in height, but they may extend from heights of fifty to seventy miles. The mean velocity of their drift is 121 miles per hour, and the predominating direction to the eastward, but there is no quarter to which these lofty cosmic clouds may not be carried. Of 78 enduring meteoric streaks motion was found to be directed to points at or between north-east and south-east in 37 cases, while to the points north-west to south-west there were only 24. The individual velocities varied from nil to 360 miles per second. In some cases a moderate speed of twenty-seven or thirty miles per hour was indicated. Certain streaks gave evidence of a series of differing currents underlying each other, the upper sections drifting in different directions to the lower.—*Nature.*

The Possibilities of Powdered Coal*

As Shown by Its Combustion Characteristics

By W. G. Wilcox

INDUSTRIAL efficiency and the smooth operation of the machinery of industry require continuous supplies of power, materials and labor. These are of equal importance in that the lack of any one of these is equally disastrous.

The wonderful work being done by women in Great Britain and France shows us that we also have great reserves of labor hitherto unsuspected and as yet practically undeveloped. When we regard the percentage of available men put in the field by both France and Great Britain—when we know that their industrial production is nevertheless carried on today at a high peak due to the utilization of women in industry, we can rest assured that the solution of our own labor shortage will follow along identical lines. The problem is by no means unsurmountable.

Power and materials, the other two factors that make up the balanced ration of industry, are bound up in each other. No matter how great the resources in raw material, these will be of no value unless the power necessary for transportation, manufacturing and fabrication is available. The greatest source of power is through the combustion of fuels. The situation in regard to fuel is so alarming as to call for the most careful consideration. Production of fuel scarcely meets consumption. Regional Director for the United States Railway administration, R. H. Aishton, formerly president of Chicago and Northwestern Railway states, that "There were times last winter when there were not four hours fuel in the city of Chicago between freezing people to death and keeping them warm." This is not the statement of an alarmist but of a man who, as director of all the great coal shipping railroads of the Middle West, knows the facts. Concomitant with the greatest demand for coal we have ever experienced we find the great natural gas field of West Virginia failing alarmingly. This brings into the list of coal consumers new users who have formerly depended on natural gas. At the same time the fuel oil is steadily becoming harder to obtain and almost prohibitive in cost. The oil fired forge furnaces of the East and the copper reverberatories and cement kilns of western Texas, Arizona and Utah, the potash producers of Nebraska and the apartment houses of Seattle, alarmed at the fuel oil situation must and are seeking coal as their salvation. This means another new demand for coal, a further burden on railroad transportation. As the railroad must have more coal to haul more coal the seriousness of the situation increases geometrically.

For this situation with all the elements of danger it presents there are three possible solutions.

1st. Stimulation of the production and transportation of fuel.

2d. Developing efficient methods for utilizing low grade fuels hitherto practically unused, and

3d. Burning fuel so much more efficiently than we now do that the amount available will be adequate for all needs.

An estimate of the possibility of speeding up coal production and coal transportation can be left to those who are at present arguing the pros and cons of whether it is the railroad or the mine which limits production. At best there does not seem to be much reason to expect any great increase in production.

Our greatest opportunity for success in meeting the fuel situation lies in the efficient combustion of both low-grade and high-grade fuels. It is far wiser to save avoidable losses than to increase supply and thus compensate for losses. It is preeminently the patriotic and professional duty of the chemist and engineer to work for the more efficient utilization of fuel. We should, therefore study critically the lines along which we should work. Among the more efficient types of combustion is the use of powdered fuel. By considering the nature of powdered coal as a fuel and its combustion characteristics we can learn its possibilities in the present fuel situation. The requirements necessary in perfect combustion show the weaknesses of present methods and the possibilities of powdered coal combustion.

What are the known avoidable losses in combustion? What are the essentials necessary for combustion efficiency?

Assuming the correct furnace and flue design, and proper and controlled draft, the essentials of good combustion are:

1st. *Complete oxidation of all the combustible in the coal to avoid loss of combustible in ash and up the stack.*

The loss of unburned carbon in the ash will vary with different types of fuel, different types of ash and the percentage of ash in the coal. It will also vary with the type of stoker used and boiler load carried. In hand fired practice it will vary with the skill of the fireman; and in producer operation it will vary according to the quality of the coal, type of producer and operating conditions.

Using an Illinois coal of the following analysis:

Sulfur	5½%
Volatile Matter	34.0%
Fixed Carbon	42.0%
Ash	18½%

The results of one of the large users in the Middle West show the following losses in the ash.

Actual per cent of coal lost:

Over-feed stokers—25% unburned carbon in the ash	4.6%
Chain grate stokers, 35% unburned carbon in the ash	6½%
Hand fired, 35% upwards unburned carbon in the ash	6.5% and upward

This particular consumer has two different types of stokers and also does a large amount of hand firing. His consumption is over 100 carloads of coal per day; operation is under the direction of skilled technical men who have actual data as to losses.

In producer operation using a good grade coal, 20 per cent of unburned carbon in the ash is the minimum figure. Under bad conditions when poor, fine wet coal was used and with variable steam pressure, as high as 55 per cent unburned carbon will be found in the ash even with a first class modern producer.

With any type of stoker or producer the loss due to unburned carbon in the ash increases with the increasing ash content. This is not a straight line function partly due to the human element while the increase in unburned carbon with increasing ash is affected considerably by the nature of the ash, its fusibility, etc. Certain coals although of high heating value offer enormous difficulties to efficient operation when put through a producer, burned on grates or on stokers. A case in point is a coal obtained in southwestern Virginia not far from Bristol, Tenn. This coal runs over 14,000 B. T. U. and contains under 8 per cent ash. Occurring in this coal are fine laminations of pure crystalline transparent calcite which is present in just sufficient amount to flux the other ash materials and give continuous trouble, from clinkering. Even in a modern mechanical producer this coal is a source of continuous trouble and interruption of operation. Due to the mechanical occurrence of the ash washing does no good.

Another case is a Colorado coal of the following analysis:

Ash	6.66
V. M.	43.76
F. C.	49.58
Sulfur	0.93
B. T. U.	12,886.00

The ash of coal melts, runs down on the grates and freezes there while the coal itself disintegrates and chokes up the fire.

There is, of course, also the loss of unburned carbon up the stack which although as much as one or two per cent under some conditions should be small with good operation.

2d. *Control of combustible and air* is absolutely essential, if we are to secure maximum flame temperature with a corresponding increased rapidity of heat transfer. The more rapid the heat transfer in the furnace or boiler the higher the capacity of the furnace and in general the greater the efficiency. This may well be shown by the following example. The theoretical flame temperature for hydrogen is 2,010° C.; while with 25 per cent excess air, this figure drops to 1,764° C. This fact has long been realized in boiler practice and considerable emphasis has been placed on high content of CO_2 in the flue gasses and a minimum amount of excess air.

3d. *Control of flame length.* In order to maintain in a furnace the conditions which the design of the furnace, the operation, or the metallurgical process occurring therein, requires, it is essential that the length of the flame be under control. An example is found in a recent development in firing copper reverberatory furnaces. For a long time it has been a practice to fire copper reverberatories with an insufficient amount of air, admitting the amount of air required to complete combustion at ports along the side of the reverberatory. It has recently been found with oil fired reverberatories that if the number of oil burners firing into the furnace is increased and the mixture of oil and air so adjusted as to give complete combustion with a short, hot flame, the capacity of the furnace is increased in some cases as much as 50 per cent, while the fuel ratio is better than anything yet obtained with oil in reverberatory practice. This is also true of powdered coal fired reverberatories. In this particular operation it has been found that a short, hot flame leads to most efficient operation and highest furnace capacity; but there are other processes in which the reverse is true.

In changing types of fuel, for example in changing from the hand firing of coal to powdered coal combustion, the economies met with are usually far greater than those which can be figured out from the known losses. The increase in capacity is usually so great that it can only be attributed to increased furnace efficiency. This increased furnace efficiency in all probability follows from the fact that the operator is now able to maintain the flame length and type of combustion for which that particular furnace design is best suited. When in changing from hand fired practice to powdered coal combustion, it is found that only from 30 to 40 per cent as much coal is used as formerly, the greater proportion of the saving is very evidently due to change in the efficiency of the furnace.

4th. *That type of combustion which is to be most efficient must possess flexibility in capacity.* Flexibility in combustion means rapid response. Only in this way can a cold furnace be brought to heat very quickly or a standby boiler come up to peak load rapidly. This makes for efficiency because it reduces the fuel consumption during the standby period. Many operations also requires considerable variation in heat input at different stages of the operation; in order to secure highest efficiency under these conditions, extreme flexibility as to "combustion load" is demanded.

5th. *Control of the nature of the combustion.* In many operations it is not only necessary to heat uniformly, quickly and efficiently, but it is equally important to maintain a certain chemical condition in the furnace. This condition may be oxidizing, reducing or neutral. In any case the control of combustion should be such that the desired condition may be maintained within very close limits; failure to do so means a waste of fuel. Maintaining an oxidizing condition without ability to control it within close limits, will result in having present too much of an excess of air, which will lower flame temperature, lessen output, lower furnace efficiency and reduce fuel efficiency. Likewise a reducing condition, unless maintained within close limits, means that fuel is needlessly wasted. If the operation demands a neutral condition, there may be some loss due to spoiling of product, unless there is the ability to maintain the neutral condition quite exactly.

6th. *One stage combustion.* The best example of two stage combustion is the producer. The producer affords in many of its applications an overall efficiency which is considerably higher than that obtained by other methods. Nevertheless we should clearly realize that in the process for making producer gas there is an inherent loss of at least 20 per cent because of the inability to gassify without forming a certain percentage of CO_2, due to heat losses at the producer and losses in sensible heat from the gas between the producer and the point at which it is used.

There is another serious objection to two stage combustion. When combustion is completed, the final flame temperature is lower than in a one stage process. Unless we resort to such devices as the recuperator or regenerator, high temperatures cannot be reached. Furthermore, a two-stage combustion results in "cracking" some of the most valuable constituents of the coal with the formation of smoke in the furnace and soot in the producer. This has been shown very well by Kreisinger, Augustine and Ovitz in Bulletin 135 of the Bureau of Mines, in their study of the combustion of coal and furnace design.

Having considered the essentials for efficient combustion, we can correctly estimate the value of powdered coal as an efficient fuel, by studying its characteristics, and seeing to what extent these make it possible to maintain the essentials of good combustion. In the same way we can also ascertain the conditions demanded for successes in the combustion of pulverized fuel.

The simplest way to regard the combustion of coal is that it is a reaction between fuel and oxygen. It is therefore a heterogeneous system, consequently the velocity of the reaction and its completeness will depend upon the surface exposed by the solid, the pressure of the

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reacting gas and the intimacy of the mixture. By grinding an inch cube of coal so fine that 85 per cent will pass a 200 mesh screen, we have increased the surface exposure from six square inches to approximately 1,800 square inches. We have therefore increased the velocity of combustion approximately 300 fold. By doing so, we have immediately changed the characteristics of the fuel. We now have a fuel relatively 300 times more active than the inch cube of coal, a new type of fuel which has in it inherent possibilities not met with in lump or slack fuel. By increasing the surface exposure 300 fold, we have speeded up combustion proportionately. This carries with it a further effect. The increase in combustion velocity also increases the rapidity of heat evolution, and consequently quickly raises the temperature of the rest of the material. This temperature rise, which is much more rapid than in the normal combustion of coal, will double the velocity of combustion each rise of 10° C. The increased velocity due to greater surface exposure and that due to temperature rise are superimposed on each other so that we have with pulverized fuel a combustion which is hundreds of times faster than when burning lump coal.

Having a finely divided fuel it is possible to form a mixture of fuel and air so intimate that each small particle of coal is surrounded by the proper amount of air. In this condition, by maintaining the proper velocity of the air current, the fuel can be carried into the furnace in suspension and there burned completely, efficiently and rapidly.

It is of course a simple matter to mechanically control the amount of powdered coal delivered to the furnace in a given time. It is also quite possible to control the amount of air delivered with the coal. If, then, we deliver to the furnance an intimate mixture of air and powdered coal and have control of the amount of coal dust and air delivered, we have the prime essentials for highest combustion efficiency. These are the possibilities in utilizing coal in powdered form. The degree to which they are attained depends entirely upon how carefully we study the characteristics of the fuel before and during combustion.

The amount of coal dust delivered to the furnace can be controlled simply and positively by using as a feeder a properly designed screw, operated at variable speeds. It is also a simple matter to control the volume of air admitted with the fuel. But the highest efficiency possible with this type of fuel will not be obtained unless we work out a correct way in which to mix a finely divided solid with the air.

A study of the methods for making such a mixture, immediately shows that the methods commonly used in making uniform mixture of two miscible liquids or a uniform solution of a solid in a liquid or the methods used in mixing finely ground solids are not only useless in this case, but will actually separate the coal dust from the air. Ordinary mixing is done by agitation; this agitation is usually accomplished by baffling, stirring, shaking or similar devices. When, however, such methods are applied to a mixture of gas and finely divided solid, the solid tends to separate out due to its much higher specific gravity. This, in fact, is the principle of the well known cyclone dust collector. Any mixing device which results in such agitation of the dust and air as to give a centrifugal effect, will tend to separate out instead of mixing the air and the dust. Any mixing device along these lines must necessarily fail to give an intimate, perfect mixture.

The importance of intimately mixing the coal dust and air cannot be exaggerated. The rapidity of combustion is a direct measure of the intimacy of mixture. This is well illustrated by comparing the ordinary gas flame with the flame obtained in the Bone Combustion System. As you are aware, the Bone System consists in forcing the proper proportions of air and gas through a diaphragm having numerous small interstices which results in a mixture that is nearly perfect. When this mixture is ignited on the other side of the diaphragm, we have only a film of flame.

The poorer the mixing the longer the flame. The flame simply outlines the area in which combustion is taking place and the length of the flame is a measure of the time element necessary to accomplish combustion. This time element—other conditions being equal—is absolutely a function of the intimacy of mixture. This has already been noted by Breckenridge some ten years ago, when in Bulletin No. 325 of the United States Geological Survey, page 171, he stated:

"The conclusion is reached that the velocity of combustion decreases enormously from the surface of the fire to the rear of the combustion chamber, where it is relatively very small, the practical application is that little is to be gained by adding further length of smooth combustion chamber, which would be commercially as poor an investment of capital, as to add to the length of a Corliss engine cylinder and stroke; we must resort to thorough mixing."

On page 178 of the same bulletin, Breckenridge further stated:

"Mere length of combustion chamber counts for little —that mixing is what counts."

These two excerpts from Breckenridge's study of 400 steaming tests have since been amply confirmed by the work of Kreisinger, Augustine and Ovitz, in bulletin No. 135 of the Bureau of Mines, entitled "The Combustion of Coal and Design of Furnaces." The work of these investigators confirmed and emphasized the previous observations of Breckenridge and they quote him as I have. They also state on page 130:

"Evidently, the length of the flame depends not only on the nature of the combustible, the excess of air, and the rate of firing but also to a large degree on the rate of mixing of the combustible gases with the oxygen of the air. It has been shown that the tendency of the gases is to flow in parallel streams even when the air was introduced into the furnace in many small streams through the tuyeres of the furnace."

So far we have considered this type of fuel from the point of view of the possibilities which it affords. We have also studied the characteristics of the mixture of coal dust and air in order to ascertain what methods should be employed to insure delivery to the furnace of an intimate, controlled mixture of fuel with the requisite amount of air. A fuel having the great possibilities offered by a finely divided combustible, is of extreme importance especially under present conditions. Because of these possibilities, all of which are capable of being realized and which are satisfied by commercial equipment now on the market, there is less excuse for permitting inefficient operation with this fuel than with stoker or hand fired practice. Apparatus, properly designed and fundamentally correct in principle, will give proper efficiency. Such apparatus by giving in intimate and controlled mixture of fuel and air to the furnace will permit the highest furnace efficiency.

Just as in the past there has been a remarkable failure to realize the necessity for intimately mixing air and coal dust, neither has there been sufficient consideration of the characteristics of this fuel when burning. Powdered coal has the characteristics of a rich fuel of somewhat higher kindling temperature than producer gas, natural gas or fuel oil. To illustrate the fact that it is a rich fuel, we can compare the available B. T. U. in a cubic foot of a correctly proportioned mixture of powdered coal and air and the available B. T. U. in a cubic foot of a correctly proportioned mixture of pure methane and air. Taking a Pittsburgh vein coal (heating value 14,157 B. T. U.) of the following analysis:

Volatile	35.4%
Fixed Carbon	58.5%
Ash	6.1%

We find that a cubic foot of a correctly proportioned mixture of coal dust and air has available 107 B. T. U., while a mixture of pure methane and the proper amount of air has available per cubic foot, 62.3 B. T. U.

As a further illustration is shown by the theoretical maximum flame temperature of several fuels.

THEORETICAL MAXIMUM FLAME TEMPERATURE USING COLD AIR

Hydrogen	2,010° C.
Carbon Monoxide	2,050° C.
Natural Gas	1,806° C.
Pure Methane	1,958° C.
Pittsburgh Coal (analysis given above)	3,470° C.

The rapidity of combustion and the completeness of combustion of a mixture of coal dust and air depends upon a number of factors:

1st. The velocity and pressure at which it is passed into the combustion chamber. If the velocity of the incoming stream of powdered coal and air is above the velocity of flame propagation, combustion will not take place until the mixture has slowed down to a point that it does not exceed the velocity of flame propagation. When powdered coal is fired at high pressure and high velocity, combustion frequently does not begin until a point four to six feet from the mouth of the burner. A similar example is found in the plumber's blow torch when too much air is used, or in the Bunsen burner when the gas pressure is too high. High pressure, high velocity firing not only slows down combustion thus increasing the size of combustion chamber necessary, but has a destructive action on the furnace. It has been well established that high velocities in the combustion chamber or a blow torch effect due to firing at high pressure (whether oil or gas be used as a fuel)are always very destructive to the brick work. This action is increased in high pressure firing of powdered coal since in addition to the erosional effect of gases at high temperature traveling at high velocity, there is a fluxing action by the melted ash. Furthermore, with such high velocity combustion, the slagged ash will be carried along mechanically, leading to further furnace troubles. In one case this resulted in a serious deposit of slag on the mud drum of a vertical waste heat boiler at the end of a long reverberatory furnace. Slowing down the velocity not only hastens combustion, but makes it possible to eliminate much of the slag. When the velocity is low the coalesced particles of slagged ash are either larger than will be carried by the velocity of the gas or this condition is so nearly approached that a slight change in direction of the flame will result in dropping out the slag. Thus, in addition to being correct combustion and necessary in order to avoid excessive furnace maintenance costs, low pressure, low velocity combustion permits by slight change in flame direction dropping out a very large percentage of the slagged ash in the early part of combustion, where it can be removed and will not interfere seriously with efficient metallurgical operations.

The velocity of combustion is not only dependent upon the fineness of the particles of coal, intimacy of mixture and the velocity of the stream of combustion and air, but is affected by the temperature of the combustion chamber. The kindling temperature of a mixture of powdered coal and air is higher than either that of oil or gas; consequently for successful and complete combustion, it is necessary that the combustion chamber be maintained above a certain minimum temperature and that combustion is practically complete before the products of combustion pass over the heat absorbing surfaces. Just as you can extinguish a gas flame by passing over it a piece of wire gauze, so the effect of a chilling surface will be even more marked with this combustible material than burning gas, since the particle of coal is infinitely larger than a molecule of gas and the kindling temperature is also higher. This has a direct application in the successful firing of locomotive type boilers, water tube boilers and return tubular boilers. If the combustion of powdered coal is not sufficiently developed before the flame enters the tubes of the locomotive type boiler, combustion will be checked and coked coal settle out in the tubes. If on the other hand combustion is sufficiently developed before the flame is brought in contact with the heat absorbing surface, complete combustion and high efficiency are obtained. In any furnace operation and in furnace design, this must be borne in mind if the success is to be expected.

A study of the flame developed by a low pressure, intimate mixture of coal dust and air shows that combustion is extremely rapid. In a reverberatory copper furnace in Florence, Colorado, where this type of combustion is used, coal burned at the rate of approximately one ton an hour develops a flame which vanishes within six feet of the burner, combustion being complete at that point. In order to bring out exactly what this means, let us translate it into terms of natural gas, in which case the fuel consumption would be approximately 26,000 cubic feet per hour or 433 cubic feet per minute. You can picture to yourself this quantity of gas being burned at low pressure and developing a flame only six feet long. Gas samples taken in the flame, show a content of CO_2 as high as 16 per cent only five feet from the mouth of the burner. This will give an example of the rapidity with which combustion can be obtained and the extremes which are possible in shortening the flame. It is equally possible with proper equipment to lengthen the flame until it will spindle out a distance as great as 100 or 120 feet. However, with an intimate controlled mixture, this must be done by supplying insufficient air. Under such conditions combustion is incomplete and the flame spindles out because combustion continues to develop throughout the length of the furnace as air leakage supplies additional oxygen. This is an additional proof of the statement previously made that the length of flame is an actual measure of efficiency of mixing and the adjustment of the fuel-air ratio.

Thus, it is seen that we have changed entirely the characteristics of coal as commonly known. Powdered coal is a fuel of extreme flexibility in that the amount burned can be varied within wide limits. It is a fuel which develops a flame whose length can be adjusted. The character of the flame can be altered to suit the metallurgical operation. In short the basic fuel, coal, has acquired the characteristics of oil or gas, but with better and closer control than in the case of oil or gas. Furthermore, the possibilities of this fuel are not only capable of realization, but are actually being utilized in commercial practice today. To the flame characteristics of a rich fuel, developing a flame like oil or gas, is added a degree of control not yet obtainable in burning either oil or gas. This statement is made advisedly. The possibilities of such combustion for the improvement of processes, for fuel economy, for increasing output, through its ease of control and elimination of heavy labor, are today realized by few. Due to the psychological attitude of labor and the scarcity of skilled operatives, it is far more difficult than ever before to secure high efficiency and good operation in hand firing, stoker firing or in producers, in short wherever such efficiency depends upon constant watchfulness and hot, heavy, disagreeable

work. For these conditions powdered coal substitutes an ease of control such that the equipment can be handled by an old man or a boy, while it is so simple that a man of ordinary intelligence can soon be taught all that is necessary for good efficiency in operation. The possibilities of such control in the place of present day combustion methods, which permit high efficiency only by the most strenuous effort, through substituting for these a type of combustion whereby high efficiency is easily obtained, are certainly of great importance to us at the present time.

To you who are in touch with many diversified chemical industries, the possibility of maintaining within close limits, heating conditions which are oxidizing, reducing or neutral at will, conditions which once adjusted will remain constant—barring mechanical or electrical interruptions—will undoubtedly suggest many cases where such combustion will offer new economies and betterments in your processes. A good example of this is shown in a powdered coal installation in a malleable iron foundry in Buffalo. The positive and simple control offered by their equipment has not only resulted in the highest fuel ratio yet reached in malleable iron practice, namely between five and six pounds of castings per pound of coal, but also through maintaining a slightly reducing condition in the annealing oven the oxidation of the cast iron pots has been so reduced that the costs of pots per ton of castings has been cut from $2.25 to 83 cents. These two results are a concrete proof of the possibilities of this type of combustion. The high fuel ratio shows efficient combustion; the decrease in pot cost shows control of combustion; and the high fuel ratio in conjunction with the maintenance of a reducing condition shows exactness of control.

A still more striking example of the possibilities of controlled combustion may be cited of a powdered coal installation now being made. In this particular process a cast iron container is maintained continuously at a temperature of 1,000° C. This is not only close to the melting point of the material, but is a temperature so high that the oxidation caused by the unavoidable excess of air met with in ordinary methods of combustion results in enormous maintenance costs due to quick failure of the container. In this installation it is confidently believed that the combustion can be so controlled as to cut oxidation to a minimum so that the life of the container will be greatly increased.

The Fuel Administration has wisely districted the coal fields of this country. In doing so they have upset in many cases what has been standard practice for years in some of the industries. The cities of Iowa have for years used anthracite for house heating; today they must use Iowa and Illinois coal. The malleable iron foundries of Chicago have in the past bought Elkhorn coal from Kentucky with which to melt iron in the air furnace; today they are confronted with the problem of using high sulfur, low grade, Middle Western fuel. While temporary relief will undoubtedly be granted through permits to use high grade coal for melting, it is probably only a question of time before they will be compelled to work out successful methods for burning the lower grade coals of their immediate vicinity, from which they should naturally draw their supply of fuel. Nebraska must learn to use her lignites, as must the Dakotas. Western Texas must do the same. Seattle, which has in the past heated apartment houses with fuel oil, must learn to do so with the lignitic coals of Washington.

While these communities are facing the problem involved by the use of these low grade fuels, every user is experiencing a marked decrease in the quality of his coal, regardless of the source. In the J. R. Aldred lecture delivered at Johns Hopkins University this year by Mr. E. G. Bailey, he shows that due to the enormous demand for fuel, shortage of labor and other conditions, the ash content in coal has increased during the year of 1917 at least 5 per cent, resulting in an increase in coal consumption, due to the decreased heating value and lower efficiency, which reaches as high as 10 per cent. Figuring on a basis of 600,000,000 tons of coal produced and marketed last year, 30,000,000 tons of dirt, slate and rock were handled in excess of what the coal would normally contain. At a price of $2.50 f. o. b. mine and a freight rate of $1.50 per ton, the consumer has paid $120,000,000 for worthless material. The additional cost of firing this coal, repairing furnaces, stoker and locomotives and the cost of handling the ashes, will add some millions of dollars more.

The coal consumer today is obtaining not only a poorer grade coal than formerly but a coal much more difficult to burn efficiently, due to increased content of sulfur balls, slate and bone. Not only is this true, but a big variation in the quality of coal leads to further inefficiencies. Stoker practice and our present settings are largely designed for a particular type of coal of a certain grade. The flexibility of such equipment in handling efficiently considerable variations in quality of fuel and nature of ash is limited. Under such conditions powdered coal by reason of its characteristics as a fuel offers us in many cases a solution of the problem.

In burning low grade fuels in suspension the only loss in efficiency is that due to lower flame temperature caused by the increasing amount of ash and the heat lost in the ash. Coals running as high as 30 to 40 per cent ash can be successfully burned; combustion will be complete and maximum flame temperature for that fuel will be obtained. The only difference between burning a fuel of this type and a high grade fuel is the difference in flame temperature and the heat loss in the slagged ash. An ash whose slagging character would lead to enormous difficulties in producer or stoker operation will simply melt the easier when the coal is burned in powdered form and can therefore, be dropped out earlier in the furnace, which in many cases constitutes an actual advantage. The lignite fuels of the Middle West and the Far West can be burned successfully and are being burned successfully in powdered form. An enormous field is opened up through ability to burn with efficiency these lower grade fuels. It will eliminate long hauls of fuel by our railroads, release motive power and cars, and conserve our fuel reserves.

An unusually good illustration is found in two coals previously mentioned, one a Virginia coal more than 14,000 B. T. U. and less than 6 per cent ash, and the other a Colorado coal. Both of these are practically unavailable as fuels when using stokers, grates or producers, because of the chemical nature of the ash and its mechanical form. When, however, these coals are pulverized, the distribution of the ash in the lump coal has no effect, while the low melting point of the ash in many cases offers a decided advantage. These coals both afford splendid fuels of high heating value when burned in powdered form. The Colorado fuel is being burned successfully in this way. The River Smelting and Refining Company, which is burning this Colorado fuel has cut the fuel requirements per ton of ore smelted in a reverberatory of one-eighth that necessary when this coal was burned on grates.

It has been the object of this paper to discuss the unusual characteristics of powdered coal as a fuel; not only the characteristics of the fuel before being burned—which of necessity dictate the principles which must be made use of in designing proper equipment and which gives us an idea of the possibilities offered by this fuel, but its more striking possibilities have been shown. Many of these are actually being obtained commercially today. From your knowledge of your own industries, no doubt many other possibilities will suggest themselves to you.

The Tinting Strength of Pigments

THE power of one pigment to impart its color to a mixture containing a second pigment is greatly increased if the first pigment coats over and hides the particles of the second one; the smaller the particles of the first are, relatively to the second, the less of the former is required to coat the particles, and consequently the greater becomes the tinting strength of the first pigment. Anything which favors the adhesion of the fine to the coarse particles promotes the coating-over effect, and increases the tinting strength of the first pigment, while with particles of the same size and with equal adhesive power to promote the coating tendency, the greater the hiding power the higher is the tinting strength. With proper control of the other factors it is stated that it ought to be possible to estimate hiding power from tinting strength, if the pigment to be tested is very fine compared with the one with which it is mixed, and if it actually coats over and hides it. Other physical properties, besides color, of mixed powders are dependent very largely upon relative size of particles and the coating-over effect; thus the relative size has an important bearing on the color of a mixture of two pigments one of which is inert. The coarser the inert pigment is, the larger is the amount which may be added without appreciably affecting the shade of the mixture. This accounts for the fact that ground barytes, silex, and asbestine are used so generally as inert fillers, as each substance consists of particles far larger than those of the majority of the pigments with which they are mixed.—Note in *Jour. Soc. Chem. Ind.* on an article by T. R. Briggs in *J. Phys. Chem.*

New Theory of the Spontaneous Firing of Haystacks

THE author criticizes the commonly accepted theory of spontaneous combustion in stacks, especially the assumption that combustible gas and carbon are produced at relatively low temperatures by "dry distillation." He proposes a theory based on observations made on the drying of medicinal plants. The first phase of heating is regarded as due to oxidation processes under the influence of the plant oxidizes and at the expense of the air present in the stack. This phase results in a small rise of temperature but ceases when the oxygen in the stack has been exhausted. After this the chief role is played by reductases, which act energetically between 50 degrees and 70 degrees C. and effect the de-oxidation and eventual carbonization of such substances as amino-acids and carbohydrates. It is to the accumulation of oxygen withdrawn by the reductases that the danger of ignition is due, for the reduction processes themselves would not produce sufficient heat to ignite the material. The general precautionary measures recommended are, therefore, thorough drying of the hay before stacking (to minimize enzymic action), and thorough aeration of the stacks, which may be built in horizontal layers with air spaces between.—Note in *J. Soc. Chem.* on an article by A. TSCHIRCH in *Schweiz. Chem. Zeit.*

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